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[Continued from page 1.]

JOEL STEBBINS.

In the first part of this paper were given the results of the observations of *Algol*, made with the selenium photometer, and let us now consider what conditions in the system of *Algol* will account for the variations in light. Since Vogel's classic determination of the radial velocities before and after light minimum, the eclipse theory has been regarded as established. The presence of a secondary minimum in the light curve now proves that the companion is not wholly dark, and it is evident that we have to deal with a bright and a relatively faint body, which I shall designate as *Algol* and the companion.

As a first approximation let us assume that the orbit is circular, that both bodies are spheres, and further that they are devoid of extensive atmospheres which would cause a decrease of intensity from center to limb, such as we know does exist in the case of the Sun. The most obvious explanation of the continuous variation of light between minima is that the companion keeps one face toward *Algol*, and is brighter on that side due to radiation received from the primary. I therefore assume that the companion rotates uniformly once in the period of revolution, and that it is divided into two hemispheres each uniformly intense. While this last assumption is probably far from the truth, it is sufficient for the accuracy of the observations.

In the calculations which follow, I have converted stellar magnitudes into relative light, changing the unit as convenient. First, taking the light of α *Persei* as unity, let

PLATE III.

MEMBERS OF THE ASTRONOMICAL AND ASTROPHYSICAL SOCIETY OF AMERICA AT THE AUGUST 1910 MEETING, AT HARVARD COLLEGE OBSERVATORY.

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In the calculations which follow, I have converted stellar magnitudes into relative light, changing the unit as convenient. First, taking the light of α *Persei* as unity, let

ϕ = the angular phase, or true anomaly counted from minimum,
L = the corresponding total light of the system, as seen from the Earth,
L_1 = the light due to *Algol* + the faint hemisphere of the companion,
$2s$ = the excess of light emitted by the bright hemisphere over the faint hemisphere of the companion.

It then easily follows that

$$L = L_1 + s\,(1 - \cos\phi). \qquad (1)$$

Each normal magnitude between minima in Table II furnishes a value of L for the corresponding ϕ, and solving the 11 equations by the method of least squares, I obtain for the two unknowns:

$$L_1 = 0.8507 \pm 0.0033,$$
$$s = 0.0201 \pm 0.0029,$$

or in terms of stellar magnitude, referred to α *Persei*, we have

$$L_1 = 0.176 \text{ mag.} \pm 0.004 \text{ mag.}$$
$$s = 0.025 \text{ mag.} \pm 0.003 \text{ mag.}$$

Using these values of L_1 and s, the light-curve between minima was computed, and is shown in Fig. 3. If we assume no variation between minima, the squares of the residuals give $[vv] = 0.001691$, and the addition of the term in s reduces this to $[vv] = 0.000470$, or to the order of one-fourth.

It is somewhat tempting to introduce another unknown which will express the ellipticity of *Algol* due to tidal action, but the residuals between minima are now so small that I should consider the result of such a computation as illusory. For the present it seems justifiable to state that, within the limits of error, the observations are represented by the simple assumption that both bodies are spheres, and that the companion is uniformly bright over each of the two hemispheres.

We are now ready to take up the elements of the system of *Algol*, as they may be determined from the variation throughout the eclipsing phase. In 1880 Professor E. C. Pickering* first worked out a determination of the relative distance and dimensions of the components of *Algol*, and his theory was extended by Harting.† I shall follow the method of Harting, with some changes necessitated by the influence of the light of the companion.

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* *Proceedings of the American Academy of Arts and Sciences*, 16, 1, 1880.
† *Untersuchungen über den Lichtwechsel des Sternes β Persei*, Munich, 1889.

Let the radius, the surface-intensity, and the total light of *Algol* each be taken as unity, then the elements to be determined are:

κ = the radius of the companion,
r = the radius of the relative orbit,
i = the inclination of the orbit,
λ = the surface-intensity of the faint hemisphere of the companion,
$\lambda+\lambda_1$ = the surface intensity of the bright hemisphere of the companion.

During the eclipse, we may consider the disks of the two stars projected on a plane perpendicular to the line of sight, and in this projection let

2η = the angle at the center of *Algol*, subtended by the common chord,
2ξ = the similar angle at the center of the companion,
ρ = the distance between centers,
M = the area common to the projected disks,
v = the projection of the true anomaly in the apparent orbit,
P = the period = 68.816 hours,
t = the time in hours from minimum,
L = the total light as seen from the Earth.

Then the following equations give the light L at any instant, when the elements are known:

$$\phi = 360^\circ \frac{t}{P}$$

$$\operatorname{ctn} v = \cos i \operatorname{ctn} \phi$$

$$\rho = r \frac{\sin \phi}{\sin v}$$

$$\cos \eta = \frac{1 + \rho^2 - \kappa^2}{2\rho} \qquad (2)$$

$$\sin \xi = \frac{1}{\kappa} \sin \eta$$

$$M = \kappa^2 \xi - \rho \sin \eta + \eta$$

$$L = 1 - \frac{M}{\pi} + \kappa^2 \lambda, \text{ near principal minimum,}$$

$$= 1 - \frac{M}{\pi} (\lambda + \lambda^1) + \kappa^2 (\lambda + \lambda^1),$$

near secondary minimum.

In practice it is best to assume a set of elements, compute L for the phase of each normal magnitude, and from the residuals derive corrections to the elements. Confining ourselves to the principal eclipse, the corrections $\delta\kappa$, δr, and δi are given by equations of the form

$$\frac{\pi}{2}\,\delta L = \kappa\,(\pi\lambda - \xi)\,\delta\kappa + \frac{\rho \sin\eta}{r}\,\delta r - \frac{r^2 \sin 2i \cos^2\phi \sin\eta}{2\rho}\,\delta i. \qquad (3)$$

From equations (2) and (3) the elements may be derived after λ is known. We can now make use of the observations outside of the principal eclipse, and let L with different subscripts represent the light received from the system by an observer on the Earth; also put $M = M_\circ$ at either minimum. We have then

$$L_1 = 1 + \kappa^2\lambda, \quad \textit{Algol} + \text{faint side of companion},$$

$$L_2 = 1 + \kappa^2(\lambda + \lambda_1), \quad \textit{Algol} + \text{bright side of companion},$$

$$L_M = 1 + \kappa^2\lambda - \frac{M_\circ}{\pi}, \quad \text{at principal minimum},$$

$$L_m = 1 + \kappa^2(\lambda + \lambda_1) - \frac{M_\circ}{\pi}(\lambda + \lambda_1), \quad \text{at secondary minimum}.$$

On referring to (1) it is seen that with the proper unit

$$\kappa^2\lambda_1 = 2s.$$

The values of L_1 and L_2 are already known in terms of the light of α *Persei*. L_M and L_m may be found graphically, but when approximate elements are known, $M_\circ$ and L_M are derived from the light-ephemeris.

The solution of the foregoing equations gives

$$\frac{M_\circ}{\pi} = L_1 - L_M$$

$$\lambda_1 = \frac{L_2 - L_1}{\kappa^2} \qquad (4)$$

$$\lambda = \frac{\pi(L_2 - Lm)}{M_\circ}\,\lambda_1$$

The unit of light to which the L's must be referred is defined by

$$L_1 = 1 + \kappa^2\lambda,$$

and it was found from (1) that L_1 corresponds to a light which is 0.176 magnitude fainter than *a Persei*. Hence, each successive value of κ or λ requires that all computed and observed lights be referred to a new unit.

The approximation of the elements by (2), (3), and (4) is then as follows. Obtain preliminary values of κ, r and i and substitute κ in (4), which gives λ_1 and λ; compute by (2) the light-ephemeris for a number of epochs, and form the residuals,

δL; find the corrections $\delta\kappa$, δr, and δi from three or more observation equations (3); substitute the corrected κ in (4), changing the light-unit, and the new values for λ_1 and λ complete the set of elements. The ephemeris is now recomputed, and the process of correction repeated until satisfactory elements are secured.

Some valuable suggestions for finding preliminary values for κ, r, and i may be found in a paper by Schlesinger.* In the first approximations it is unnecessary to use all of the observations to form equation (3), perhaps the easiest method being to draw a light-curve and select 3 points which are sufficient to give κ, r, and i. When sufficiently approximate elements have been derived the final solution may be made, using all of the observations, and forming normal equations in the usual way.

In applying this method to the case in hand I first assumed that the light-curve is symmetrical near principal minimum, and I arranged the normal magnitudes in Table II in order, without regard to the sign of the phase. Averaging each successive pair of normals, I obtained the results in Table III. The phase is now given in decimals of an hour, and the light is referred to difference of magnitude 0.244 as unity, which is the final adopted brightness of *Algol*. The residuals are derived from a comparison with the light-ephemeris computed final elements.

TABLE III

COMBINED NORMAL MAGNITUDES NEAR PRINCIPAL MINIMUM

Phase	Difference of Magnitude	Light	O.—C. Light
h			
0.28	1.360	0.358	— 0.002
0.74	1.180	0.442	+ 0.021
1.18	1.085	0.461	— 0.004
1.61	0.925	0.534	— 0.008
2.31	0.665	0.679	— 0.001
2.80	0.485	0.801	+ 0.024
3.55	0.360	0.899	— 0.014
4.07	0.255	0.990	— 0.001
4.53	0.195	1.047	+ 0.004

It is not necessary to set down here the details of the numerical work by which different sets of elements were obtained. Let it suffice to give merely the results of the successive approx-

* *Publications of the Allegheny Observatory*, 1, 123, 1909.

imations. Starting with the magnitudes in Table III, and using equations (2), (3), and (4) as indicated, the different elements are as follows.

TABLE IV

ELEMENTS

	I	II	III
κ	1.00	1.15	1.14 ± 0.05
r	4.54	4.85	4.77 ± 0.05
i	84.°0	82.°6	82.°3 ± 0.°3
λ_1	0.049	0.038	0.038 ± 0.007
λ	0.045	0.054	0.050 ± 0.010
$[vv]$	0.002318	0.001810	0.001315

An inspection of the numerical solution for Elements III shows that one more approximation will reduce $[vv]$ by about 2 per cent, but this refinement seems unnecessary. The probable errors of κ, r and i were computed, in the usual way, from the weights derived from the normal equations; but for the probable errors of λ and λ_1 it was assumed that the probable errors of L_m and L_M are respectively ± 0.003 and ± 0.005 light units. In Fig. 5 the system of *Algol* as seen from the Earth has been drawn from the data of Elements III.

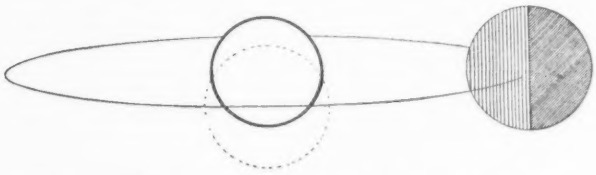


FIG. 5. THE SYSTEM OF ALGOL AS SEEN FROM THE EARTH.

As these elements are considerably different from those previously derived for *Algol*, it may be of interest to note the reason for this result. My value for κ shows that the companion is about one-seventh larger in diameter that *Algol*, while previous determinations have yielded a value of about $\kappa = 0.75$. The question at once arises as to whether there is something in the selenium photometer which gives an unusually large range of magnitude for this star. In Table V is a comparison of this range with that determined at Harvard,* and by Müller.† For the maximum with the selenium photometer I have taken an average magnitude between minima.

* *Harvard Annals* 50, 202, 1908.

† *Op. cit.*, p. 193.

TABLE V

RANGE IN MAGNITUDE OF ALGOL.

	Harvard	Müller	Selenium Photometer
	Mag.	Mag.	Mag.
Maximum.....	2.1	2.43	0.15 fainter than α *Persei*
Minimum.....	3.2	3.55	1.37 fainter than α *Persei*
Range.....	1.1	1.12	1.22

There is no evidence of a large difference in scale between my results and those derived from visual observation, but in any event it is my opinion that the selenium photometer gives more nearly the absolute scale than can be obtained visually.

Assuming for the moment that the companion gives no light, and that the range of variation is 1.22 magnitudes, it follows that 0.675 of the bright disk is obscured at minimum, which gives 0.82 as the least possible value of κ. It is evident that if the companion is not wholly dark, or if it is not wholly projected against the bright star at principal minimum, then the radius, κ, may be considerably larger than unity.

From elements III the adopted light curve has been computed from (I) between minima, and from (2) during eclipse. The light L has been converted into stellar magnitudes, and as thousandths of a magnitude determined with the selenium photometer would have no meaning in either the Harvard or Potsdam systems, the computed and observed magnitudes are still referred to α Persei.

TABLE VI

ADOPTED LIGHT-CURVE OF ALGOL

Phase	Difference of Magnitude	Phase	Difference of Magnitude
h		h	
± 0.0	1.37	30.0	0.129
± 0.5	1.31	31.0	0.138
± 1.0	1.15	32.0	0.152
± 1.5	0.95	33.0	0.170
± 2.0	0.77	34.0	0.186
± 2.5	0.61	34.67	0.189
± 3.0	0.47	35.0	0.188
± 3.5	0.35	36.0	0.177
± 4.0	0.265	37.0	0.160
± 4.5	0.200	38.0	0.142
± 4.90	0.174	39.0	0.131
+ 5.0	0.174	39.6	0.128
7.5	0.170	40.0	0.128
10.0	0.166	45.0	0.136
15.0	0.156	50.0	0.147
20.0	0.144	55.0	0.158
25.0	0.134	60.0	0.168
29.8	0.128		

This light-curve has already been shown in Figure 3, and it should be understood that the curve there drawn has been derived entirely by computation from the elements, except that I made a graphical determination of the times of minima.

The duration of the eclipse is easily found from the equation

$$\cos \phi_1 = \frac{\sqrt{r^2 - (1 + \kappa)^2}}{r \sin i}$$

where ϕ_1 represents the true anomaly at first or last contact. Using elements III, there follows

$$\text{Duration of eclipse} = 9^h.80.$$

The conclusion of Müller that the principal minimum lasts 12 or 13 hours has therefore not been verified, but he was not fortunate in securing enough observations near the critical times of beginning and ending to establish this longer time. Rödiger* has used Müllers light-curve as a basis of deriving the elements of *Algol* with allowance for an assumed decrease in intensity of the bright disk from center to limb, but likewise his results are not confirmed. Judging from the beautiful accordance of Müller's observations near the time of greatest eclipse, it is my opinion that if he had been able to push his observations to the limit throughout the entire period of the star's variation, he would have detected the secondary minimum.

COMPARISON OF ALGOL WITH THE SUN.

As any direct determination of the intrinsic luminosity of a star requires that its distance be known, we are fortunate in having a pretty fair determination of the parallax of *Algol*.

In Table VII are collected all the determinations for this star, and in each case there has been assumed a parallax of the comparison stars, in order that the result for *Algol* will be an absolute parallax.

TABLE VII

PARALLAX OF ALGOL

Observer	π	Weight
	″	
Chase	+ 0.05	3
Russell	+ 0.01	3
Pritchard	+ 0.07	1
Flint	+ 0.12	1
Adopt	+0″.05	

* *Untersuchungen über das Doppelsternsystem Algol*, Königsberg, 1902.

With this value of the parallax it is now easy to compute the luminosity, or total light of *Algol* as compared with the Sun. Let l be the luminosity, π the parallax, and M the stellar magnitude of the bright component of *Algol*; also let S be the stellar magnitude of the Sun. From simple considerations we have

$$\log l = -2 \log \sin \pi - 0.4\,(M - S).$$

Adopting $M = 2.2$, and $S = -26.6$, there follows:

TABLE VIII

		⊙=1	Stellar Magnitude
l	Total light of *Algol*	51.	2.2
$lk^2\lambda$	Total light of faint hemisphere of companion	3.3	5.2
$lk^2(\lambda+\lambda_1)$	Total light of bright hemisphere of companion	5.9	4.6

The principal source of error in the comparison with the Sun lies of course in the parallax.

Since the computed luminosity varies inversely as the square of the parallax, it is not possible to assign even an approximate value of the luminosity to a star whose parallax is much less than 0″.10. In the present case where we have the mean of the results of four observers it is highly probable, however, that the computed luminosities are of the right order, and we may feel safe in concluding that the companion of *Algol* is a body which gives off much more light than our Sun.

The stellar magnitudes in the last column of Table VIII are quite independent of the parallax, and signify that if the bright star could be shut off from our view, the companion would appear as varying on its own account, the range being from 4.6 to 5.2 magnitude.

DIMENSIONS OF THE SYSTEM OF ALGOL

As is well known, Vogel's determination of the variable radial velocity of *Algol* led to the first approximation of the actual diameter in kilometers of any of the fixed stars; but unfortunately Vogel's numerical results are often quoted without due emphasis on his necessary assumption that the two components are of the same density. For a comparison with my light-curve there are available the results by Schlesinger

and Curtiss* from the observations in 1906 and 1907. In the conventional notation, the elements which are applicable are as follows:

TABLE XI
ALLEGHENY SPECTROSCOPIC ELEMENTS

	Schlesinger	Curtiss	Adopted
e	0.031	0.060	0.05
ω	+44°	− 3°	+21°
$a \sin i$	1,570,000 km	1,630,000 km	1,600,000 km

There was a discrepancy between the time of light-minimum as determined photometrically and as demanded by these velocity determinations, amounting to 1½ to 2 hours. Since my correction to the light ephemeris in 1909-1910 amounts to $-1^h\,16^m$, a portion of this discordance is removed; but as I have learned from Director Schlesinger that the orbit of *Algol* is still being investigated at Allegheny, it seems best to wait for a comparison of spectrographic and photometric observations taken near the same epoch.

As only one spectrum was discernible on the plates, the spectroscopic elements refer to the motion of the bright component about the center of mass. Evidently, when $\omega = 0°$ the distances between centers of the projected disks are equal at the two minima, and in view of the small value derived for ω, my determination of the relative brightness of the components has not been materially affected by neglecting the eccentricity. Likewise a simple calculation shows that the assumption of a circular orbit introduces no appreciable error into the computed variation of the light during the eclipses. In my judgment, it is as yet impossible to determine the eccentricity of this orbit from photometric observations, and all the numerical results which have been derived from the asymmetry of the light-curves by visual observers are spurious. Nevertheless, it may be of passing interest to compare the intervals between minima as determined graphically from my light-curve, and as computed from the Allegheny elements. The total period being $68^h.816$, I find the following times by which the secondary follows the principal minimum:

$e = 0$	$34^h.41$
From light curve	34 .67
From Allegheny elements	36 .46

* *Publications of the Allegheny Observatory*, 1, 25, 1908.

It is apparent that the photometric result is not in agreement with the Allegheny determination of 3 years previous, but in view of the difficulty of finding the exact time of secondary minimum from a variation of only 0.06 magnitude, I attribute little significance to this fact.

Before deriving plausible values of the dimensions in the system of *Algol*, on the basis of the spectroscopic orbit, let us consider the probability of various assumptions as to the relative masses of the two bodies. Although we have many theories of stellar evolution, to my mind the most direct evidence which bears upon this question is that found by Schlesinger and Baker* in a comparative study of spectroscopic binaries. They have announced the rule thus far without exception, that where the spectra of both components of a close binary are visible, the brighter star is always the more massive. Therefore when the spectrum of the fainter component is not visible, the mass of the bright star is presumably much the greater. With this in mind, I have thought it best to compute the dimensions on two assumptions: first, that the two bodies are of equal density, and second, that *Algol* has twice the mass of the companion.

The Sun being taken as unity, let m and m_s represent the masses, and d and d_s the densities of the two bodies, the subscript referring to the companion. Changing to conventional notation, we have $r = a + a_s$. The combined mass is given by

$$m + m_s = \frac{4}{10^{20}} \frac{(a + a_s)^3}{P^2},$$

where the distances are expressed in kilometers and the period in days. From $a \sin i = 1{,}600{,}000$ km and $i = 82°.3$ it follows that $a = 1{,}610{,}000$ km. To compute $(a + a_s)$ we have the two assumptions

(1), $d = d_s$	(2), $m = 2m_s$
$a + a_s = a\left(1 + \frac{1}{\kappa^3}\right)$	$a + a_s = 3a$

The radius of the Sun being 697,000 km, simple computations give the results in Table X, where each quantity is referred to the Sun.

* *Publications of the Allegheny Observatory*, 1, 135, 1910.

TABLE X

		(1), $d=d_s$	(2), $m=2m_s$
R	Radius of *Algol*	0.81⊙	1.45⊙
$R\kappa$	Radius of companion	0.92	1.66
m	Mass of *Algol*	0.04	0.37
m_s	Mass of companion	0.06	0.18
d	Density of *Algol*	0.07	0.12
d_s	Density of companion	0.07	0.04
σ	Surface-intensity of *Algol*	78.	24.
$\sigma\lambda$	Surface-intensity of faint hemisphere of companion	3.9	1.2
$\sigma(\lambda+\lambda_1)$	Surface-intensity of bright hemisphere of companion	6.9	2.1

On the first assumption there results a great surface-intensity for a small mass, while in the second case, where the companion is supposed to be relatively rare, the masses and radiative powers are much nearer those of the Sun. On the basis of these figures alone, it would seem that the second assumption is nearer the truth.

It seems to be often overlooked that the mean density of an *Algol* star may be determined without any arbitrary assumption, when we know the ratio of the radii of the two components, and their relative separation, that is, the elements κ and r. The first determination of the density of *Algol*, which I have been able to find, was by Maxwell Hall*. He tacitly assumed that the components are of the same density, though as a matter of fact, since the mean density of the system is fixed by the values of κ, r, and the period, any hypothesis as to the relative densities of the two bodies will lead to the same computed mean density. The first rigorous treatment of the problem was by Mériau,† and afterwards Roberts‡ and Russell¶ independently published striking numerical results for stars of the Algol type, showing that these systems are all extremely rare.

If we represent by d_0 the mean density of the system of *Algol*, and express the period P in days, then the following equations have been established, the numerical constant being a logarithm

* *Observatory*, 9, 224, 1886.
† *Comptes Rendues*, 122, 1254, 1896.
‡ *Astrophysical Journal* 10, 308, 1899.
¶ *Ibid.*, 315, 1899.

$$d_0 = [8.1277]\ \frac{r^3}{(1+\kappa^3)P^2}$$

$$d = [8.1277]\ \frac{r^3}{P^2} \cdot \frac{m}{m+m_s}$$

$$d_s = [8.1277]\ \frac{r^3}{\kappa^3 P^2} \cdot \frac{m_s}{m+m_s}$$

The first equation is immediately applicable, but to obtain the densities of the components, we must know the ratio of the masses. As was pointed out by Roberts, the factors

$$\frac{m}{m+m_s} \qquad \text{and} \qquad \frac{m_s}{m+m_s}$$

are each less than unity, but if we put them successively equal to 1, we shall obtain the upper limit to the value of the density of each component. Physically this signifies, in each case, the assumption of zero mass for one component, and the true density will always be considerably less than the limit. Introducing the numerical values of κ, r, and P, there follows:

Mean density of the system .....0.07⊙
Limiting density of *Algol*.....0.18
Limiting density of companion.....0.12

It is to be hoped that a means of detecting the spectrum of the companion may be found, which will at once give us the actual masses, diameters, and densities of the two bodies, subject only to the errors of observation. In this connection, it is barely possible that the extra sensibility of selenium at the red end of the spectrum* may have been a factor in the detection of the secondary minimum in the light curve, and it would be of interest to know the spectral type of each hemisphere of the companion.

We now have numerical data on which to base a plausible explanation of the greater luminosity of the companion on the side toward the primary. Two reasons at once suggest themselves: first, that the companion reflects the light of the bright star, and second, that the radiation from *Algol* is so intense that it is sufficient to heat the near hemisphere of the companion up to incandescence.

* The color-sensibility curve of the selenium cell, Giltay 93, which was used in the observations of *Algol*, will be found in the *Astrophysical Journal*, 27, 185, 1908.

From the values of κ and r, and the solid angle at the center of *Algol* subtended by the companion, the fraction of the total light intercepted by the companion is found to be 0.015. Hence it is quite impossible that the relative light reflected from the bright side of the companion should amount to the previously computed value $\kappa^2\lambda_1=0.049$. It seems, therefore, that the increase in brightness of one hemisphere must be due to the heating effect of the intense radiation emitted by *Algol*.

Consider the sphere concentric with *Algol*, and of radius equal to that of the relative orbit. The radiation received per unit surface of this sphere is $1/r^2=1/22.8$ times the radiation emitted per unit surface of *Algol*. This fraction represents roughly the relative radiation received by the companion. On the hypothesis of equal density, the surface intensity of *Algol* is 78 and it would follow that the companion receives 78/22.8, or nearly 4 times as much light per unit surface as is emitted by the Sun. Presumably this value is too high, and it refers only to a limited portion of the spectrum. Of course the determination of the total energy of the radiation received by the companion is an entirely different problem, but in any event these figures are suggestive.

The increase of luminosity on one side of the companion, as shown by my light-curve, is a striking independent confirmation of the results of Nordmann.* From measures of the relative intensity of different portions of the visible spectrum, he has derived a value of the effective temperature of *Algol*, and from this he concludes that the radiation at the distance of the companion is sufficient to raise a body to incandescence. "Il est donc probable que, par le seul effet de ce rayonnement et independamment de sa chaleur propre, une partie de la surface du satellite d'*Algol* tournée vers l'étoile principale, est portée à l'incandescence." Although all determinations of stellar temperatures are as yet open to question, and the parallax of *Algol* is so small as to introduce uncertainty into the results, the main conclusion of Nordmann is well confirmed by my observations.

The question of the interaction of the radiation of two components of a close variable star has not been considered heretofore, because of the small accuracy obtainable in photometric measures. It is evident that such an effect will not be discernible where the two bodies involved are of the same

* *Bulletin Astronomique*, 27, 145, 1910

order of brightness, but in many *Algol* variables where the primary is a star of great intrinsic brilliancy, and the companion relatively faint, there is every reason to suppose that future observations will demonstrate that the conditions in *Algol* are typical of this class of stellar system.

SUMMARY.

1. It has been demonstrated that for bright stars the selenium photometer, attached to a 12-inch telescope, yields results which are considerably more accurate than have ever been obtained by visual or photographic methods.

2. An application of this new device to observations of *Algol* has led to the discovery that the companion, far from being dark, gives off more light than our Sun, and in addition is much brighter on the side which is turned toward the primary.

3. A discussion of the photometric and other results for *Algol* gives the following principal facts concerning this system:

FROM THE LIGHT-CURVE

..	Radius of *Algol*	1.00
κ	Radius of companion	1.14 ± 0.05
r	Distance between centers	4.77 ± 0.05
i	Inclination of orbit	$82°.3\pm0°.3$
..	Surface-intensity of *Algol*	1.00
λ	Surface-intensity of faint hemisphere of companion	0.050 ± 0.010
$\lambda+\lambda_1$	Surface-intensity of bright hemisphere of companion	0.088 ± 0.012
..	Total period	$68^h.816$
..	Duration of eclipse	$9^h.80$
$d_\odot$	Mean density of the system	$0.07\odot$
..	Limiting density of *Algol*	$0.18\odot$
..	Limiting density of companion	$0.12\odot$

FROM $\pi = 0''.05$ SUN $= -26.6$ MAG., *Algol* $= 2.2$ MAG.

		$\odot=1$	Stellar Magnitude
l	Total light of *Algol*	51.	2.2
$lk^2\lambda$	Total light of faint hemisphere of companion	3.3	5.2
$lk^2(\lambda+\lambda_1)$	Total light of bright hemisphere of companion	5.9	4.6

FROM $a \sin i = 1{,}600{,}000$ km, TWO ASSUMPTIONS

		$d=d_s$	$m=2m_s$
R	Radius of *Algol*	$0.81\odot$	$1.45\odot$
$R\kappa$	Radius of companion	0.92	1.66
m	Mass of *Algol*	0.04	0.37
m_s	Mass of companion	0.06	0.18
d	Density of *Algol*	0.07	0.12
d_s	Density of companion	0.07	0.04
σ	Surface-intensity of *Algol*	78.	24.
$\sigma\lambda$	Surface-intensity of faint hemisphere of companion	3.9	1.2
$\sigma(\lambda+\lambda_1)$	Surface-intensity of bright hemisphere of companion	6.9	2.1

In conclusion, I beg to acdnowledge my indebtedness to Dr. F. C. Brown, in collaboration with whom many of the preliminary experiments were made; also to Dr. F. W. Reed, and Mr. Percy F. Whisler for efficient assistance in taking the observations of *Algol*. I also desire to thank the Rumford Committee of the American Academy of Arts and Sciences for successive grants of $200 and $350 which enabled me to carry on this work.

Urbana, Illinois. Jan. 1911.

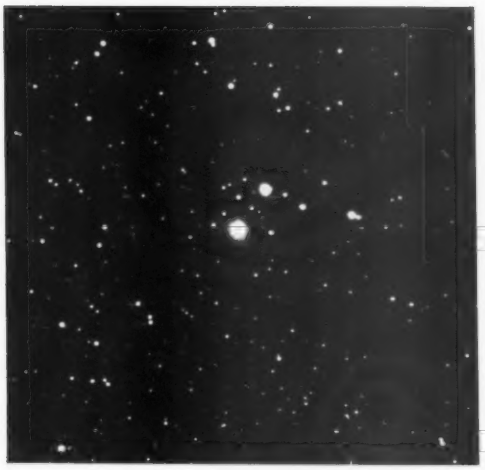
FEBRUARY AS AN ANNIVERSARY MONTH.

FREDERIC CAMPBELL, Sc. D.
President Department of Astronomy, Brooklyn Institute.

A glance at the astronomical calendar which I have been compiling for years shows that February has more than its share of anniversaries, and is linked, more than almost any other month, with the names of great astronomers. This is the more remarkable because it is the shortest month in the year.

On February 6, 1853, Dr. Thomas Anderson the Scotch astronomer, who discovered the Nova Persei in 1901, was born. February 7, 1824, William Huggins, the English astronomer and spectroscopist, was born,. February 9, 1811, Nevil Maskelyne, the fifth Astronomer Royal of Greenwich, England, after whom one of the lunar craters was named, was born. February 14, 1564, Galileo, the Italian inventor of the telescope and discoverer therewith of the four principal satellites of Jupiter, was born. February 15, 1858, William H. Pickering of the Harvard Observatory, was born. February 17, 1865, George P. Bond, the American astronomer, died. The same date, 1875, F. W. A. Argelander, the German astronomer, died. February 18, 1856, Biela, the German astronomer, after whom Biela's comet and the Bielid meteors were named, died. February 19, 1473, the great astronomer Copernicus, who placed the Sun instead of the Earth at the center of our system, was born. By an interesting coincidence, on the same date, 1856, T. J. J. See, Director of Mare Island Observatory, California who now disputes the nebular theory as taught by Laplace, was born. February 25, 1842, the French astronomer, Flam-

PLATE IV.



Region about Nova Lacertæ, from a photograph made by Prof. H. D. Curtis with the Crossley Reflector, Jan. 2, 1911; exposure $3^h\ 50^m$. The bright star in the center is the Nova; the slightly fainter star to the north is Cambridge 7788, mag. 8.8.

marion, was born. February 26, 1776, the French astronomer, Arago, was born. By another coincidence, the same date, 1878, the Italian astronomer, Secchi, died. February 27, 1906, the American astronomer and head of the Smithsonian Institute, Samuel P. Langley, died.

In a way most interesting of all, on February 29, 1820, the odd day of leap year, our American astronomer, Lewis Swift, was born; though he still lives, 91 years later, he has had but 21 birthdays, yet has been director of two observatories, has discovered fifteen comets and 1,000 nebulae, and has seen Halley's comet on two of its periodical visits,—a very confusing statement except for the addition of the odd day of his birth. The writer recently received an autograph letter from Dr. Swift, written from his home at Marathon, N. Y., where his dimmed sight awaits the perfect vision with which he expects soon to see God's worlds hitherto "seen through a glass darkly."

Various interesting and important events have also occurred in February. In 1866 the month had no full Moon, a thing which had not occurred in human history and will not again occur for 2,500,000 years. February 10, 1896, a meteorite burst 15 miles above Madrid, the concussion causing great damage. February 12, 1831, there occurred an annular eclipse of the Sun, visible in southern states. February 22, 1901, Dr. Thomas Anderson, of Scotland, discovered his Nova in Perseus, at 2:40 A.M., this being his second Nova. February 28, 1843, the great comet of that year was seen at noon with the naked eye.

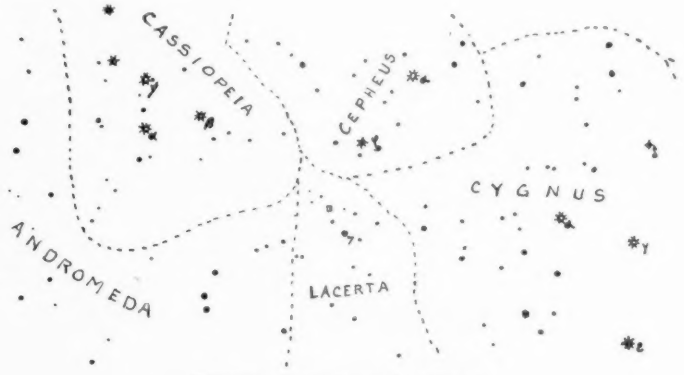
A NEW STAR IN LACERTA.

H. C. WILSON.

As will be seen by the Harvard *Astronomical Bulletin* No. 439, which appears in another place in this number of POPULAR ASTRONOMY, a new star has recently appeared in the constellation Lacerta, an inconspicuous group of stars between Cassiopeia and Cygnus. It was discovered by Espin in England and announced by telegram December 30. The announcement states that the star is of the eighth magnitude and that its spectrum contains two bright lines.

From the collection of photographs of that region taken at the Harvard Observatory it is found that the star was invisible on November 17, 1910, but appeared on November 23 and December 7. Its photographic magnitude was then about 5.00. On December 30 it had waned to about 7.0.

At Lick Observatory observations were begun on the night after receipt of the announcement and a number of excellent spectrograms have been obtained with the 12-inch and 36-inch telescopes. A photograph of the immediate region of the *nova* taken by Professor H. D. Curtis with the Crossley reflector is reproduced in Plate IV. The photograph covers an area roughly 20′ square. Only two bright stars appear in this region, the brighter of the two being the *nova*. The other bright star near the center of the picture is DM + 51°.342, magnitude 8.7, or Cambridge No. 7788, magnitude 8.8. Many faint stars which appear on the original negative have been lost in the process of reproduction. No nebulosity is shown around the *nova* although the exposure was prolonged to nearly four hours.



REGION ABOUT NOVA LACERTAE.

The accompanying diagram shows the position of the new star with reference to the neighboring bright stars. The little square in the center of the diagram is of about the size of the area shown upon the photograph. It is roughly midway between α Cassiopeiae and α Cygni, but on a line joining ε Cygni to α Cassiopeiae, and a little to the west of a line through α and ζ Cephei prolonged to meet the line just mentioned. The fourth magnitude star 7 Lacertae is about two degrees southwest from the *nova*.

PLATE V.

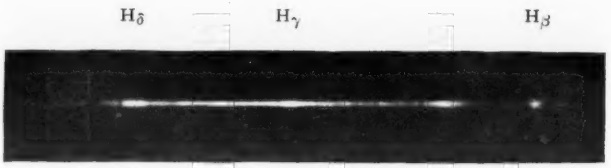


Fig. 1a.

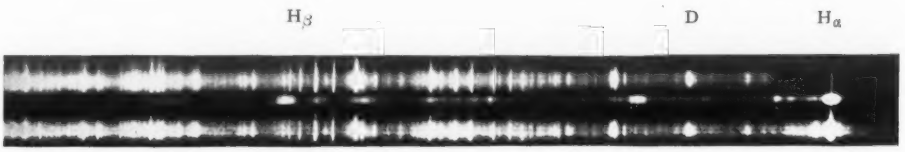


Fig. 1b.

PHOTOGRAPHS OF THE SPECTRUM OF NOVA LACERTÆ MADE BY ASTRONOMER W. H. WRIGHT AT LICK OBSERVATORY.

From measures of three photographs taken with the Crossley reflector Dr. Curtis finds the place of the *nova* to be

α 1900.0	δ 1900.0
$22^h\ 32^m\ 9^s.31$	$+52°\ 14'\ 58''.5$

At my request Professor Wright has written the following note concerning the spectrum of the *nova*.

Lick Observatory, Jan. 13, 1911.

NOTE ON THE SPECTRUM OF NOVA LACERTAE.

W. H. WRIGHT.*

Photographic observations of the *nova* have been made on practically all clear nights since its announcement on December 31, through the offices of the Harvard College Observatory. Pending the measurement of the plates it is possible to describe only the general features of the spectrum. Fig. 1a is a reproduction of the blue and violet portion of the spectrum secured on December 31, 1910. The instrument used was a one prism slit spectrograph attached to the twelve inch (30cm.) telescope. Fig. 1b represents the visual region as photographed on January 1, 1911 with a similar instrument connected with the thirty-six-inch (92cm.) refractor. The latter exposure was kindly made by Mr. P. W. Merrill during my absence from the observatory.

In all about thirty-seven bright bands and lines are recorded. It may be that this estimate will be altered in the future by the inclusion of some of the "lines" as component parts of the "bands". In Fig. 1a the conspicuous features are the bands Hδ, Hγ, Hβ and the *nova band* λ 463. As in previous novæ in their earlier stages of development, these bright bands are accompanied on their more refrangible sides by dark lines. The displacement of the dark Hγ line to the violet is roughly 18 Ångströms.

Fig. 1b. shows numerous bright bands, by far the most conspicuous feature, visually, being the one in the yellow, perhaps identical with that observed in Nova Aurigæ and Nova Persei after the spectrum had reached the "nebular" stage.

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* Astronomer, Lick Observatory.

The band at H_a is exceedingly bright photographically, being burnt out on all but the shortest exposures. Visually however it does not compare in intensity with the yellow band just referred to. It is the latter, with the adjacent continuous spectrum, tinged a little, perhaps, with the crimsom H_a, which gives the star its peculiar reddish hue in the telescope.

The bright band corresponding in position with the D lines, which was so strong in Nova Persei is possibly present, though inconspicuous. There appears to be a dark line close to this place, and there is undoubtedly one toward the violet, which may correspond to the two sets of absorption lines observed in Nova Persei.*

The enlargements from which the accompanying reproductions were made were made by Dr. H. D. Curtis.

D. O. MILLS EXPEDITION TO THE SOUTHERN HEMISPHERE.

W. W. CAMPBELL. †

The solution of the great problems concerning the stellar system demands that observations on a homogeneous plan cover the entire sky, from north pole to south pole. Even before beginning upon the program of stellar radial velocity determinations in 1896, with the Mills spectrograph attached to the 36-inch equatorial, I realized that a determination of the motion of the solar system through space, and the solution of many similar problems, could not be placed upon a satisfactory basis until radial velocity determinations were available for the stars in the southern sky. It became a practical question of ways and means for securing these southern observations. When the subject was presented to the late D. O. Mills, member of James Lick's first Board of Trustees for the Lick Observatory, former Regent of the University of California, and generous patron of the arts and sciences, he was pleased to make provision for a southern observing station, equipped with a 37-inch reflecting telescope, 3-prism spectrograph, and

* *Lick Observatory Bulletin* 1, 46-56, 1901.

† Director of Lick Observatory.

the necessary auxiliary apparatus, and for all operating and maintenance expenses, covering a net observation period of two years. The vicinity of Santiago, Chile, was selected as a site for the observing station. The first period, including both construction and observation, covered the years 1903-1906, with Astronomer William H. Wright, of the Lick Observatory staff, in charge of the Expedition.

In 1905 Mr. Mills made generous provision to continue the observations for a second period, of five years, 1906-1911. Professor Wright returned to the Lick Observatory, and Astronomer Heber D. Curtis, of the Lick Observatory staff, assumed charge of the Expedition. Early in the second period the 3-prism spectrograph was supplemented by 2-prism and 1-prism spectrographs.

The appointment of Astronomer Charles D. Perrine, of the Lick Observatory staff, to the Directorship of the Argentine National Observatory early in 1909, made it necessary that Professor Curtis return to Mount Hamilton to take charge of the Crossley reflecting telescope. Astronomer Joseph H. Moore, of the Lick Observatory staff, succeeded Professor Curtis at Santiago in June, 1909.

The lamentable death of Mr. Mills occurred early in 1910.

I am pleased to record that Mr. Mills' son, Ogden Mills, Esq., has generously provided for two additional years of observation, 1911-1913.

No attempt is made here to give adequate description of the Expedition and its work, but the following facts will no doubt be welcomed by those who are especially interested in the subject.

Observations during the first period were obtained with the 3-prism spectrograph for 150 of the brightest southern stars, whose spectra contain accurately measurable lines. Very few of these stars are north of declination — 30 degrees. The manuscript copy embodying the detailed results of these observations has been ready for the printer nearly three years, the delay in publication having been due to lack of funds. The work is now rapidly passing through the University Press, Berkeley, thanks to the private generosity of Mrs. Phoebe A. Hearst, Regent of the University of California. About forty of the stars on the list have been found to vary in velocity, due to the presence of close massive companions.

The program of observation for the second period of work included all stars down to the 5.0 visual magnitude, four

observations or more to each star, excluding only those whose spectra do not contain lines measurable with reasonable accuracy. The observations during this period will in fact exceed those required by the program just described, for observations have already been secured of more than one hundred stars fainter than visual magnitude 5.0. During the second period the majority of the observations have been obtained with 2-prism dispersion.

The number of spectrograms secured up to December 1, 1910, during both periods, was 3,608. These related to about 725 stars, including a large number of stars with variable velocities, and a considerable number with lines so poorly defined that their velocities cannot be measured satisfactorily from 3-prism and 2-prism spectrograms. Very few of these stars are north of declination — 20 degrees.

The most satisfactory statement which I can now make concerning the work is that all the spectrograms secured up to December 1, 1910, have received definitive measurement and reduction.

The additional period of two years will be utilized to measure the motions of stars fainter than 5.0 visual magnitude, to observe the motions of as many nebulae as is practicable with 2-prism and 1-prism spectrographs, and to study a few of the apparently most interesting spectroscopic double star systems discovered in the earlier years of the Expedition.

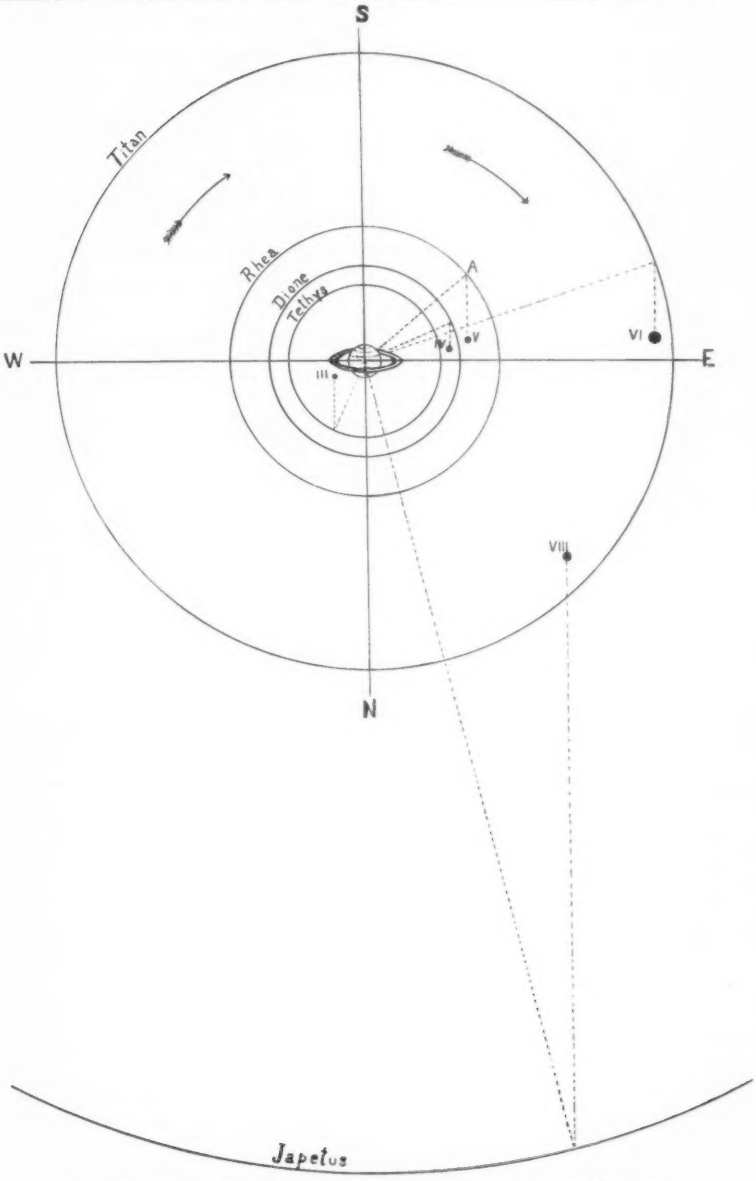
Lick Observatory, University of California. Jan. 12, 1911.

A METHOD OF IDENTIFYING THE SATELLITES OF SATURN.

WILLIS L. BARNES.

The November issue of POPULAR ASTRONOMY contains an article by Leo Holcomb accompanied by *Pencil Sketches* of Saturn with a request that some one verify his observations of its satellites, and for an identification of certain points of light which were marked as doubtful.

In compliance with this request and for the purpose of encouraging other amateurs who may desire to indulge in this most fascinating pastime, I venture to offer the following simple



ORBITS OF THE FIVE BRIGHTEST SATELLITES OF SATURN SHOWING THEIR REAL AND APPARENT POSITIONS ON NOVEMBER 4, 1909, AT 8h 30m P. M. CENTRAL STANDARD TIME.

and efficient method of locating the satellites of a planet for any given time and, for an illustration, will plat the position of the satellites of Saturn for November 4, 1909 at $8^h\ 30^m$ P.M.

For this purpose a diagram of the planet, with concentric circles representing the several orbits and two lines at right angles through the center of the planet and the positions of the elongations and conjunctions of the satellites, is drawn to a convenient scale.

From tables in the *American Ephemeris* of 1909, pages 513 and 514, are taken the elongations or conjunctions corresponding nearest in time to that of the observation and this interval between the times is noted.

Number	Name	Diam. miles	Synodic Period	Hourly Ang. Motion	Distance Miles
			d — h	°	
I-	Mimas	600	0 — 22.6	16	117,000
II-	Encela'	800	1 — 8.9	10.9	157,000
III-	Tethys	1200	1 — 21.3	8.	186,000
IV-	Dione	1100	2 — 17.7	5.5	238,000
V-	Rhea	1500	4 — 12.5	3.3	332,000
VI-	Titan	3000	15 — 23.3	.94	771,000
VII-	Hyperion	500	21 — 7.6	.7	934,000
VIII-	Japetus	2000	79 — 22.1	.2	2,225,000

From the periods of the satellites, page 512, the angular rate of motion per hour is found, and the product of this rate by the interval (as noted) gives the angular distance from the elongation or conjunction to the position of the satellite in its orbit and is set off with the protractor either direct or retrograde according as the tabular time is before or after the time of observation.

Having located the satellite on the circles representing their *real* orbits, they are reduced to their *apparent* positions as follows.

Turning to page 515, Column 5 (headed *I*), we find the elevation of the Earth above the plane of the ring in November to be $-10°\ 46'$. The minus sign indicates that the Earth is *below* the plane, and the south side of the ring is the visible one. As the plane of the ring and that of the orbits are nearly coincident, it follows that the orbits are inclined $10°\ 46'$ to an observer on the Earth. As the sine of $10°\ 46'$ is $=.18$ the minor axes of the ellipse of the apparent orbit is .18, or

approximately $\frac{1}{5}$ that of the major axis, and in order to transfer the satellites to their apparent positions they must be dropped on a perpendicular to within $\frac{1}{5}$ of their distance from the major axis W E as indicated by the vertical dotted lines, as AV on the diagram which represents Saturn and the position of five of its satellites on November 4, 1909 at $8^h\ 30^m$ P. M. central standard time. The diagram also shows that the object marked *doubtful* by Mr. Holcomb was Japetus, Satellite No. VIII.

In order to make clear the process as above outlined the computation of the position of Rhea, Satellite No. V, at the above date is here given in detail.

Nov. $4^d\ 8^h.5$ P. M. = Central Standard time.
.9 = Approximate difference between Washington and Central time.
" $4^d\ 9.4$ = Washington time of observation.
" 4 19.8 = Tabular time of Eastern Elongation.
" 10.4 = Interval between time of observation and E.E.
3°.3 = Hourly Angular Motion.

312
312

34°.32 = Angular distance from E. E.

Since the observation was made before the time of E. E., the position of the satellite would be retrograde, and the angle 34° must be laid off accordingly, as ESA, and A being the position in the real orbit, the apparent position is found by dropping the perpendicular AV.

By the aid of the accompanying table and the *American Ephemeris* the apparent positions of the eight principal satellites of Saturn can readily be laid down to a scale with sufficient accuracy for identification, even by a novice.

Charlestown, Ind.

SPECTROSCOPIC OBSERVATIONS OF THE ROTATION OF THE SUN.

JENNIE B. LASBY.

The spectroscopic study of the rotation period of the Sun has, until recent years, been confined to visual measures of lines in the less refrangible part of the spectrum. In the investigations made by Dunér and Halm, the lines employed were

the same and consisted of a pair of iron lines in the red region of the spectrum having the wave-lengths 6301.72 and 6302.71 on Rowland's scale. With the photographic method it is possible to employ a much larger number of lines and to utilize the more refrangible part of the spectrum where there is a greater number of lines, and the variety of elements which can be employed is correspondingly larger. Realizing these facts, plans were made to make a photographic investigation of the rotation period of the Sun at the Mount Wilson Solar Observatory and observations were begun in the spring of 1906.

Since the investigation was commenced five series of observations have been made. Two of these deal with lines selected from the spectrum of the general reversing layer. The first series covers a period of fourteen months, from May, 1906 to June, 1907. These plates, forty-four in number, were taken with the Snow telescope which made it possible to procure a solar image of 6.7 inches in diameter upon the slit of the spectrograph. The spectrograph is of the Littrow, or auto-collimating type with a lens 4 inches in diameter and a focal length of 18 feet, employed in conjunction with a plane grating of the same aperture. The spectra used in this investigation have been taken in the fourth order. The linear scale of the instrument in this order at λ 4200 is about 1 mm. = 0.71 Ångström unit.

The second series was begun in February, 1908, and was carried through October of that year. The plates used in this series were taken with the tower telescope, the essential features of which are a coelostat with a mirror 17 inches in diameter mounted on a track running north and south, and an elliptical second mirror 22.5 by 12.75 inches in size, used in connection with it, which sends the beam of light received from the coelostat upon a 11-inch visual objective immediately beneath it. This objective forms the image of the Sun on the slit of the spectrograph 60 feet below, at a distance of 5 feet above the level of the ground. The spectrograph employed with the tower telescope is of 30 feet focal length, and stands in a vertical position in an underground chamber, the walls of which are lined with concrete.

The same grating was used for the two series and so it is possible to make a direct comparison of the plates. The third order has been used for the second series, as against the fourth order for the first series. Since the focal length of the spectrograph is five-thirds as great there is a gain in the linear

scale so that in the 1908 plates 1 mm = 0.56 Ångström unit. The lines on the later plates were much better than on the earlier in spite of the larger scale, a result due, probably, to the fact that the definition of this grating is better in the third order than in the fourth, and still more important a cause was the excellent conditions of temperature under which the grating was working at the bottom of the underground chamber.

The apparatus used to bring the opposite limbs of the Sun together on the slit consisted of two small diagonal prisms mounted on each of two rotating brass arms. The first of these prisms was placed at the outer end of the arm, its mean distance from the center of rotation corresponding to the mean radius of the Sun's image, and could be adjusted to correspond with the varying size of the image. A second prism, which received the beam from the first and reflected it upon the slit, was mounted with the point slightly inside the center of this end immediately above the center of rotation of the brass arm. The distance between the edges of the prisms on the two arms was about 0.25 mm, which represents the distance upon the photographic plate between the spectra of the two opposite limbs. The two arms were rotated on a brass frame, and were provided at the ends with pointers by means of which readings were made on a position circle. In the case of the observations made with the tower telescope the diagonal prism attachment was more simple as it was fastened directly to the end of the spectrograph and rotated with it instead of being itself capable of rotation. For the setting of the position circle during observations, the tables for the position angle of the Sun's axis in the *Companion* to the *Observatory* were used.

Of the remaining three series, all of which were based upon plates taken with the tower telescope, two deal with the α line of hydrogen and one with λ 4227 of calcium. In general, the plates of the five series contain six exposures, one for each 15° of latitude between 0° and 75°. In the two series dealing with the reversing layer, a number of intermediate points were added, especially in the high latitudes. The heliographic latitudes of these points were reduced by means of De LaRue's reduction tables. These give, with the Sun's longitude as an argument, the position angle of the Sun's axis with reference to the north point and the heliographic latitude of the Earth. Since we know the position circle reading of the point under observation as well as the east and west line, the position angle from the

north point is known at once, and the latitude can be easily computed. A slight correction was necessary, also, since the light which passed through the slit of the spectrograph came from a point slightly inside the Sun's edge.

It was necessary in measuring the plates to have the inclination of the cross-wire in the eye-piece coincide with the inclination of the spectrum lines. To test this in the first series a solar spectrum was photographed with a long slit, having a horizontal line running through the center. This plate was used as a standard, and the vertical wire in the eye-piece of the measuring machine was carefully adjusted until it was accurately parallel to the spectrum lines after the plate had been lined up with the aid of the horizontal line. The cross wire was then clamped into position. Only a change of position of the grating or of the slit of the spectrograph necessitated a change in the adjustment. After the tower telescope was used for observations this was unnecessary, as an exposure could then be made at the pole of the Sun where, of course, the displacement would be zero and the lines of that exposure could be used to determine the inclination of the cross-wire of the eye-piece.

The region λ 4200 to λ 4300 was selected for the investigation of the rotation period of the reversing layer because it offered lines of a sufficient variety of elements within the range of a single plate. The list of lines used is given in Table I and the wave-lengths, intensities and identifications are taken directly from Rowland's table.

TABLE I.

	Element	Intensity	Behavior at Limb
4196.699	La	2	Much weakened
4197.257	CN	2	Slightly weakened
4203.730	Cr	2	Strengthened and widened
4207.566	C	1 N	Weakened
4209.144	Zr	1	Weakened
4216.136	C	1	Weakened
4220.509	Fe	3	Slightly strengthened and widened
4232.887	Fe	2	Much strengthened and widened
4233.328	Mn	4	Much weakened. This is probably not Mn but "enhanced" line of Fe
3257.815	Mn	2	Slightly strengthened and widened
4258.477	Fe	2	Much strengthened and widened
4265.418	Fe	2	Slightly weakened
4266.081	Mn	2	Slightly weakened
4268.915	Fe	2	Slightly weakened
4276.836	—, Zr	2	Weakened
4283.169	Ca	4	Strengthened and widened
4284.838	Ni	1	Slightly weakened
4287.566	Ti	1	Slightly strengthened and widened
4288.310	Ti, Fe	1	Widened
4289.525	Ca	4	Probably slightly strengthened
4290.377	Ti	2	Slightly weakened. "Enhanced" line of Ti
4290.542	Fe	1	Slightly weakened
4291.630	Fe	2	Much strengthened
4294.936	Fe	2	Probably weakened

PLATE VI.

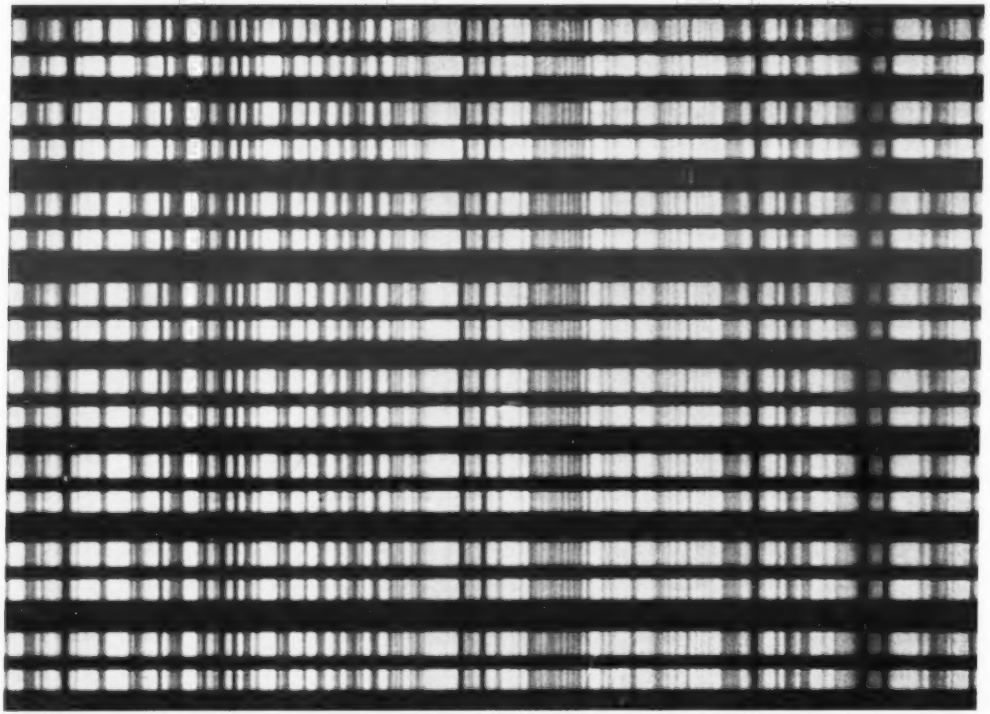


PLATE USED IN SOLAR ROTATION WORK AT THE MOUNT WILSON SOLAR OBSERVATORY.

The list of lines used for the two series varied slightly. λ 4207.566, λ 4233.328, λ 4283.169 and λ 4289.525 were not used for the first, while λ 4209.144 and λ 4294.936 were omitted in the second series.

TABLE II

DEVIATION OF THE ANGULAR VELOCITY FOR INDIVIDUAL LINES FROM MEAN VALUE. 1906—1907

	Element	0°.2	7°.7	15°.0	22°.7	29°.8	37°.8	44°.6	52°.7	59°.6	65°.6	75°.1
4196.699	La	0.0	0.0	−0.1	−0.1	−0.1	−0.2	−0.2	−0.3	−0.4	−0.3	−0.8
4197.257	CN	0.0	0.0	0.0	−0.1	0.0	−0.2	−0.1	−0.3	−0.2	−0.3	−0.8
4203.730	Cr	+0.2	+0.1	+0.1	0.0	+0.1	0.0	0.0	0.0	+0.1	0.0	+0.2
4209.144	Zr	+0.2	+0.1	+0.1	+0.1	+0.2	+0.1	+0.2	0.0	+0.2	+0.1	+0.1
4216.136	CN	−0.1	0.0	−0.1	−0.1	−0.2	−0.1	−0.2	−0.3	−0.2	−0.4	−0.8
4220.509	Fe	+0.1	+0.1	+0.1	+0.1	+0.2	+0.1	+0.1	0.0	0.0	0.0	+0.2
4232.887	Fe	+0.1	+0.1	+0.1	+0.1	+0.1	0.0	0.0	0.0	+0.1	+0.1	+0.1
4257.815	Mn	+0.1	+0.2	+0.1	+0.2	+0.2	+0.2	+0.2	+0.2	+0.2	+0.3	+0.6
4258.477	Fe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+0.2	+0.1	+0.2
4265.418	Fe	0.0	0.0	+0.1	0.0	0.0	0.0	0.0	0.0	+0.1	0.0	0.0
4266.081	Mn	0.0	+0.1	0.0	+0.1	+0.1	+0.1	+0.1	+0.2	+0.2	+0.2	+0.5
4268.915	Fe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+0.2	+0.1
4276.826	—, Zr	0.0	+0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+0.1	+0.1
4284.838	Ni	0.0	−0.1	0.0	0.0	−0.1	0.0	0.0	+0.1	0.0	0.0	0.0
4287.566	Ti	0.0	−0.1	0.0	0.0	−0.1	0.0	0.0	0.0	+0.1	0.0	+0.1
4288.310	Ti, Fe	0.0	−0.1	−0.1	0.0	0.0	0.0	−0.1	+0.1	0.0	0.0	+0.1
4290.377	Ti	−0.2	−0.2	−0.1	−0.1	−0.1	−0.1	−0.1	+0.1	−0.1	0.0	−0.1
4290.542	Fe	−0.1	−0.1	−0.1	0.0	−0.1	0.0	−0.1	0.0	−0.1	0.0	+0.1
4291.630	Fe	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.0	0.0	−0.1	+0.1	+0.4
4294.936	Zr	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.0	+0.1	+0.1	0.0	0.0

TABLE III

DEVIATIONS OF ANGULAR VELOCITY FOR INDIVIDUAL LINES FROM MEAN VALUE —1908.

λ	0°.3	4°.1	11°.2	14°.9	19°.2	29°.7	34°.1	44°.7	49°.6	60°.0	65°.0	74°.9	79°.2
4196.699	−0°.2	−0°.1	−0°.1	−0°.1	−0°.1	−0°.1	−0°.1	−0°.1	−0°.1	−0°.2	−0°.2	−0°.4	−0°.2
4197.257	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.2	−0.2	−0.2	−0.3	−0.1
4203.730	0.0	0.0	0.0	0.0	0.0	+0.1	0.0	0.0	0.0	+0.1	0.0	−0.1	−0.1
4207.566	−0.1	0.0	0.0	−0.1	+0.1	0.0	0.0	0.0	0.0	0.0	−0.1	−0.2	−0.1
4216.136	−0.1	−0.1	0.0	0.0	0.0	−0.2	0.0	−0.2	−0.1	−0.1	−0.2	−0.3	−0.4
4220.509	0.0	+0.1	0.0	0.0	+0.1	0.0	+0.1	0.0	+0.1	0.0	+0.1	+0.1	−0.2
4232.887	0.0	0.0	0.0	0.0	+0.1	0.0	0.0	+0.1	0.0	−0.1	0.0	0.0	−0.3
4233.328	−0.1	+0.1	0.0	0.0	+0.1	0.1	0.0	0.0	0.0	0.0	0.0	−0.1	−0.1
4257.815	+0.1	+0.1	0.0	+0.1	+0.1	+0.1	+0.1	+0.1	0.0	+0.1	+0.1	+0.2	+0.3
4258.477	+0.1	0.0	+0.1	0.0	0.0	+0.1	0.0	+0.1	0.0	0.0	0.0	+0.1	−0.2
4265.418	0 0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+0.2
4266.081	+0.1	+0.1	0.0	0.0	0.0	0.0	0.0	+0.1	0.0	0.0	+0.1	+0.2	+0.3
4268.915	+0.1	0.0	0.0	0.0	0.0	+0.1	0.0	+0.1	0.0	+0.1	+0.2	+0.2	+0.2
4276.836	0.0	0.0	+0.1	0.0	0.0	0.0	0.0	0.0	0.0	+0.1	0.0	+0.1	+0.1
4283.169	+0.1	0.0	0.0	0.0	−0.1	0.0	0.0	0.0	0.0	+0.1	0.0	+0.1	+0.1
4284.838	0.0	0.0	0.0	0.0	0.0	−0.1	0.0	0.0	0.0	0.0	0.0	+0.3	0.0
4287.566	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+0.1	+0.1
4288.310	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+0.1	+0.3
4289.525	+0.1	0.0	0.0	0.0	0.0	+0.1	0.0	+0.1	+0.1	0.0	+0.1	0.0	+0.3
4290.377	0.0	−0.1	−0.1	0.0	−0.1	0.0	0.0	−0.1	−0.1	−0.1	0.0	−0.1	−0.1
4290.542	0.0	0.0	0.0	+0.1	0.0	+0.1	+0.1	+0.1	+0.1	+0.1	+0.1	+0.2	−0.1
4291.630	+0.1	+0.1	0.0	0.0	0.0	+0.1	+0.1	+0.1	+0.1	+0.1	+0.1	+0.2	+0.2

One of the most important questions involved in this investigation was whether the lines of different elements give values which differed from one another in a systematic way, indicating a longer or shorter period of rotation for the various elements in the Sun's atmosphere. To facilitate rapid comparison a table has been formed showing the difference in the value of angular velocity between each line and the mean of all the lines.

In both series, it will be observed, the lines λ 4196, λ 4197, λ 4216 and λ 4290 give systematically low values. Since the first three of these lines, being due to lanthanum and cyanogen, originate at a low level in the solar atmosphere, they give evidence for the conclusion based on the results of the studjes of H_α and λ 4227 of calcium that the rate of angular rotation increases with the increase of height above the Sun's photosphere. Perhaps the most interesting deviation is that of λ 4290, an "enhanced" line of titanium. The systematically low value of angular velocity gives evidence of a relatively low level as does the fact that it is considerably shifted at the limb of the Sun. On the other hand, since enhanced lines are more prominent in the chromosphere than in the ordinary solar spectrum, it would seem to indicate a higher level.

Another important question involved in these results is whether an actual variation in the Sun's rate of rotation is indicated. To make easy a comparison of the values for the two series a table has been formed giving the values for every 5° of latitude.

TABLE IV

ϕ	v (1908)	v (1906-7)	ξ (1908)	ξ (1906-7)
°	km	km	°	°
0	2.060	2.077	14.63	14.75
5	2.043	2.056	14.56	14.65
10	2.000	2.012	14.42	14.50
15	1.943	1.954	14.28	14.36
20	1.863	1.872	14.08	14.14
25	1.761	1.768	13.80	13.85
30	1.659	1.660	13.60	13.61
35	1.537	1.532	13.32	13.28
40	1.414	1.406	13.10	13.03
45	1.274	1.274	12.79	12.79
50	1.126	1.137	12.44	12.56
55	0.967	0.991	11.97	12.27
60	0.820	0.851	11.64	12.08
65	0.677	0.711	11.37	11.94
70	0.533	0.569	11.06	11.81
75	0.396	0.429	10.86	11.77
80	0.266	0.290	10.88	11.85

It will be seen that the earlier series gives a slightly larger value between latitudes 0° and 25°, while the values between 25° and 50° are very nearly coincident, and beyond that point the earlier series again shows larger values. The discrepancy from 0° to 25° is too slight, however, to give decided evidence of a possible variation in the rate of rotation. The differences above 50° of latitude, on the other hand, are large enough to indicate either some source of systematic error in the observations or a real change in the rotation of the Sun. It would seem probable that the variation in the rotation period if such a variation exists, would be more likely to occur in the low latitudes, in the zones of sun-spot activity. Evidence is gradually accumulating, however, to show that the rotation rate is more nearly constant at the Sun's equator, and that instead of an "equatorial acceleration" we have a "polar retardation." The observations of Halm show the greatest variation in the higher latitudes, and further evidence is given here by both the low-level lines of lanthanum and cyanogen, and the high-level line of λ 4227 of calcium and the α line of hydrogen.

The close agreement of Dunér's results with those given by the 1908 series seems to indicate no real change in the rate of rotation. A comparison for the six latitudes is given below.

TABLE V

ϕ °	Dunér km	Mt Wilson km
0.4	2.07	2.06
15.0	1.97	1.94
30.0	1.69	1.67
45.0	1.27	1.27
60.0	0.80	0 81
74.9	0.40	0.40

It was shown that the motion of the reversing layer may be much disturbed in the vicinity of a solar vortex. On September 14th four plates were taken covering 75° of latitude at intervals of 15°. On this date two spots of considerable size, one at 6° south latitude, the other at 11° north latitude, were close to the west limb of the Sun, and spectroheliograph plates had shown these spots to be surrounded by immense regions of disturbance. When the measurement of these plates was begun it was found that the values at 0° and 14°.9 were far from normal. As the line λ4227 was measurable on these plates a number of settings were made on that line also.

The values are given below and compared with the normal velocity of the reversing layer.

TABLE VI

ϕ	v km	Normal v km	λ 4227 v km
0.0	1.930	2.060	2.007
14.9	1.899	1.945	1.971
29.8	1.666	1.662	1.725
44.7	1.240	1.277	1.309
62.8	0.724	0.743	0.844
75.3	0.389	0.393	0.476

It is seen that in latitudes 30° and more the values approach the normal, while at 0° and 15° the results are decidedly low. The fact that the rotation results were thus affected by disturbances in the solar atmosphere may explain the discrepancies in the values of the two series since it is known that these disturbed regions extend to the high latitudes where there are no spots, and neither series contains a sufficiently large number of observations to eliminate the influence of even a few cases of proper motion.

It seemed desirable to make a study of one of the stronger lines of calcium and λ 4227 was chosen as H and K were found impracticable because of the great change in their physical appearance at different parts of the Sun's disk according to the presence or absence of calcium flocculi.

The final results in angular velocity for the reversing layer, λ4227 and H_α both at the limb and inside the limb have been summarized in Table VII.

TABLE VII

°	Rev.Layer °	λ4227 °	H (Inside Limb) °	H (Limb) °
0	14.54	14.9	14.8	15.0
15	14.31	14.8	14.7	14.9
30	13.67	14.3	14.3	14.6
45	12.79	13.7	13.8	14.3
60	11.92	13.1	13.3	13.9
75	11.27	12.7	13.0	13.7
Pole	(11.04)	(12.5)	(12.8)	(13.6)

A comparison of the results for λ 4227 with those of the reversing layer shows that the absolute values are larger for λ 4227 and the decrease of angular velocity is much less marked toward higher latitudes.

Two series of investigations were made on the H_α line, one at points close to the limb and one about 3mm. inside the limb. The width of this line changes rapidly within a small distance of the Sun's limb and it seemed probable that this might be due to the relative level in the two cases, the effective level

being higher at the limb than that inside the limb. The results for H_α show the same tendency as those for λ 4227 only in a more marked degree. It is very evident that the hydrogen gas giving rise to H_α moves at a much higher velocity than the reversing layer, and also that the law of change of velocity with latitude is very different, the equatorial acceleration being comparatively slight.

The important facts of this investigation may be summarized as follows:

1. The general agreement of the results for the two series of investigations on the reversing layer and the close accord with Dunér's results seem to indicate that there is no marked variation in the rotation rate. If such variation does exist it seems to be confined to the higher latitudes and not to the zones of sun-spot activity.

2. The observations of both series show that different lines give different velocities. "Enhanced" lines seem to have a tendency toward low values. Lines considerably strengthened at the Sun's limb give high values in general.

3. When lines give systematically high or low values for the rotational velocity the difference becomes greater in higher latitudes.

4. The motion of the reversing layer may be greatly influenced by disturbances in the solar atmosphere.

5. The study of λ 4227 of calcium shows that the rotational velocity derived from this line is higher than that of the general reversing layer, and the decrease of velocity with increasing latitude is less marked than in the reversing layer.

6. The rotational velocities from H_α of hydrogen depend upon the distance from the Sun's limb. At the limb the values are much larger than for the reversing layer, and at 35″ inside the limb, though considerably smaller, still average larger than for the reversing layer.

7. The differences of rotational values for λ 4227, H_α at limb and H_α inside limb may be due to differences of level in the solar atmosphere.

Mt. Wilson Solar Observatory.

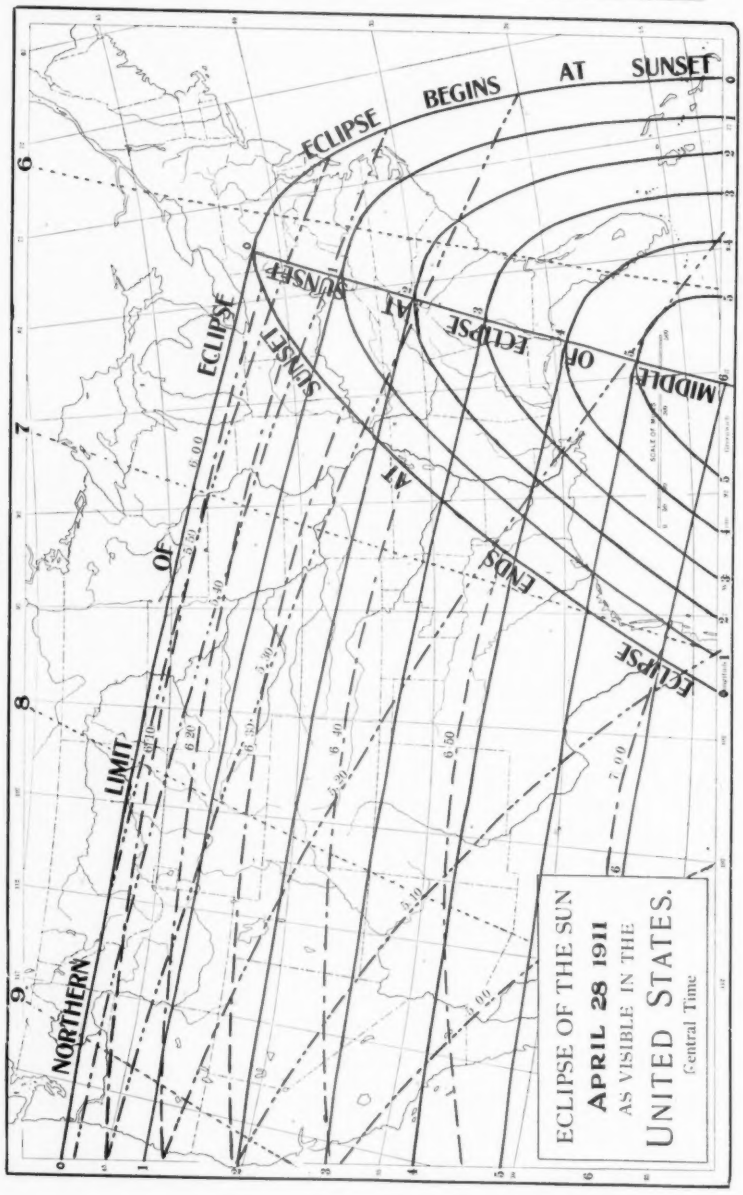

ECLIPSE BEGINS AT SUNSET
ECLIPSE AT SUNSET
MIDDLE OF ECLIPSE AT SUNSET
ECLIPSE ENDS AT SUNSET
NORTHERN LIMIT OF ECLIPSE AT SUNSET
ECLIPSE OF THE SUN
APRIL 28 1911
AS VISIBLE IN THE
UNITED STATES.
Central Time

FIG. 1.

THE SOLAR ECLIPSE OF APRIL 28, 1911, AS VISIBLE IN THE UNITED STATES.

WILLIAM F. RIGGE S. J.

The total eclipse of the Sun of April 28, 1911 will be visible as a partial eclipse over the larger part of the United States. The accompanying map will show the circumstances. The curves marked as the northern limit and as the beginning, middle and end of the eclipse at sunset, are sufficiently intelligible without explanation. The parallel ovals marked 0, 1, 2, 3, 4, 5, show the tenths of the sun's diameter eclipsed at the moment of sunset, with this difference, that to the east of the middle line the eclipse will still be increasing

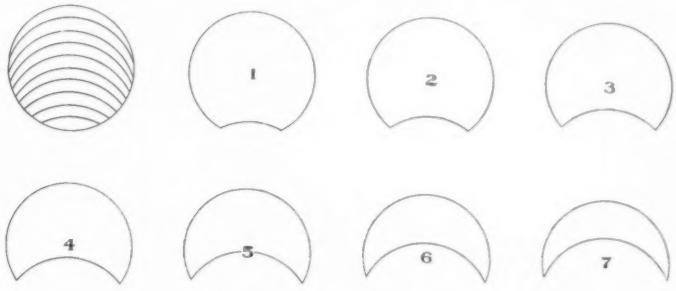


FIG. 2. APPEARANCE OF THE SUN AS VARIOUS TENTHS OF ITS DIAMETER ARE ECLIPSED.

at that time, while to the west of it, it will be decreasing.

The full lines parallel to the limit line, marked 0, 1, 2, 3, 4, 5, 6, indicate the tenths of the Sun's diameter obscured at the middle of the eclipse. The two-dot-and-one-dash lines mark the beginning of the eclipse for every ten minutes of central time, and the two-dash-and-one-dot lines show the end of it. According to them the eclipse begins everywhere before 6 o'clock and ends everywhere after it. The dotted lines 6, 7, 8, 9, show the central times of sunset.

And lastly Fig. 2 gives the appearance of the Sun as various tenths of its diameter are obscured.

Creighton University Observatory.
Omaha, Nebr.

THE INFINITUDE OF THE UNIVERSE.

FREDERICK C. LEONARD.

FOR POPULAR ASTRONOMY

To many of the ancient philosophers, the Earth was by far the most important body in the Universe. Not only did these men reason that the Earth was the most important body in infinity, but according to their hypotheses, the Earth was the very center of the Universe, around which every other material body swung. Now, however, with our present knowledge of natural philosophy, we know that the Earth is one body out of many, one out of millions, which comprise our universe. We learn that it is but one small member of a great collection of bodies which we term the Solar System. The Solar System, including the Sun which is merely a star, is a member of a vast aggregation of sidereal bodies, known as the Stellar Universe. This system, although its name would be *likely* to indicate it, is *not* supposed to fill all space; the advanced theory of today is that through infinite space are scatterred subordinate and probably isolated "universes." We cannot, however, speak with any absolute truth of physical existence beyond the bounds of *this* stellar system.

The previous brief sketch of our relation to the Universe as a whole, will probably be better understood after comparisons of the Earth to individual bodies have been made. To begin with, let us take our own Sun. The Sun is distant from the Earth approximately 93,000,000 miles; this distance is better realized after the statement is made that if it were possible for a train to travel from here to the Sun, never stopping and moving with the velocity of sixty miles per hour, it would require about 178 *years* to reach its destination. The Sun is about 850,000 miles in diameter, (the Earth nearly 8,000), and in bulk is over a *million* times larger than the Earth. The same imaginary train spoken of previously would require about five years to make an equatorial journey around the Sun. Some of the eruptive prominences on the Sun rise to heights of 300,000 miles with velocities as great as 600 miles a second, while it is not at all infrequent to find sun spots that are large enough to engulf the entire Earth without touching it. "Were the Sun placed in one pan of a mighty weighing balance," says Sir Robert Ball, "and were 300,000 bodies as

heavy as our Earth placed in the other, the luminary would turn the scale." This is illustrative of the weight of cosmical bodies.

Proceeding outward from the Sun, we reach the mighty planet Jupiter, which, in round numbers, is 1,300 times as large as our globe, and lastly we reach the distant planet Neptune which is almost 2,800,000,000 miles from the central luminary. Our train would require about 10,000 years to traverse merely the breadth of the known Solar System, traveling at its rate of sixty miles per hour!

These figures are astounding, but the numerals expressing stellar distances are incredible. The distances from here to the stars are so great that a unit known as a "light year" is employed to express them. A "light year" is the velocity of a ray of light in a year. Light travels with the inconceivable velocity of 186,330 miles per second; from this it is apparent then, that, expressed in miles, a light year is equal to nearly 6,000,000,000,000! The nearest known star to the Earth, α Centauri, one visible from the southern hemisphere, is distant more than 4¼ light years, or expressed in miles, about 25,000,000,000,000, while most of the stars are distant 50, 100, 200 and some possibly 4,000 light years! The North or Pole Star, Polaris, is distant about 50 light years, in miles, about 300,000,000,000,000, while the familiar star Vega is removed from us from 20 to 30 light years. Of the latter star, Mr. Olcott remarks, "If the distance from the Earth to the Sun equalled one-inch, the distance from the Earth to Vega would be one hundred and fifty-eight miles." Sirius, the brightest star in the entire heavens is approximately 8½ light years from us. Alcyone, the *lucida* of the Pleiades, is probably so distant that a ray of light would require nearly 270 years to traverse the distance between that star and us! At this distance, our Sun would be only about one two hundred and fiftieth as bright as Alcyone; this illustrates the fact that many of the stars are much larger and brighter than the Sun. The group of the Pleiades is doubtless so exceedingly large that a ray of light would require many years to cross it. It is extremely difficult to determine with any precision the distances from here to the stars, as they are so distant, and consequently their parallactic angles so small.

A star visible from the southern hemisphere known as Canopus, is supposed to possess an intrinsic brilliancy which exceeds that of the Sun 10,000 times at least. This star is about

(actually but not apparently), 250 times as bright as Sirius, which is 40 times as bright as our Sun. A zodiacal star known as Antares, in brightness is equal to about 900 suns like ours, while another, Arcturus, (mentioned in the Bible), says Professor F. R. Moulton, "is equivalent to about 1300 suns such as ours." Capella, a beautiful first magnitude star visible in our latitudes, is also very great in intrinsic brilliancy, being 220 times as great in light radiation as the Sun, according to Maunder's computation. Many of the stars that we see are much brighter than the Sun.

Those great aggregations of stars scattered here and there over the celestial sphere, known as the star clusters, are exceedingly large. Many are so nearly infinitely remote, that although some of the component stars may be billions of miles apart, yet in small telescopes they appear merely as hazy masses. Such is true of the Great Star Cluster in Hercules, which contains undoubtedly 6,000 stars, probably many more.* There are also fine examples of star clusters in the constellations, Centaurus, Scorpio, Canes Venatici, Scutum Sobieski, Aquarius and others. The great cluster in the southern constellation Centaurus contains probably more stars than the great cluster in Hercules. It is an interesting fact to note that there are some 30,000,000 stars down to the thirteenth magnitude, and that there are about 3,000,000 stars visible in a three-inch telescope. In our largest telescopes some 100,000,000 stars are visible, and this number is doubtless limited to the light-gathering capacity of our most powerful instruments!

Those great gaseous masses of cosmic material, termed nebula, are very distant. The Great Nebula in the constellation Orion is probably distant 1,000 light years; its distance however, is very uncertain; it may be as near as 300 light years, or as distant as 1,500, however, 1,000 light years seems to be the best approximation. The appropriate mathematical computation shows that the diameter of this mass expressed in light years, must equal to from 25 to 30, *i. e.*, it must be about as far across as the distance from here to the star Vega. If we consider the breadth of the nebula 30 light years, then in miles it is approximately 180,000,000,000,000. A great mass in the constellation Andromeda, the Great Nebula in Andromeda, is probably as large, if not larger, than the Orion nebula. Indeed, a theory

* According to the estimation of Sir William Herschel, the Hercules cluster contains some 14,000 stars.

has been expounded concerning the magnitude of this nebula, which suggests that we are looking out of the Stellar Universe *upon* it, rather than looking in *at* it.

As to the diameters of the *stars*, it will suffice to state that in one binary system, according to the work of Myers, the component stars are both more than 10,000,000 miles in diameter, with masses 10 and 21 times as great as that of our Sun. These diameters are greatly contrasted to that of the Sun. In only special cases can the diameters of the stars be computed.

In this paper I have described only a very few of the great magnitudes of the Stellar Universe; what I have left unsaid, greatly exceeds that which I have said. From all, it is apparent that the mile is an inadequate unit to express stellar distances; that is to say, distances with which we are familiar, can in no way bear comparison to celestial distances. Of these wonderful magnitudes which I have enumerated, the human mind has no conception, they must simply go to prove our place among infinities; they must illustrate the absolute infinitude of the *Universe* of the Almighty Creator!

Leonard Observatory,
Madison Pk., Chicago, June, 1910.

HALLEY'S COMET.

The Romance of Its Past.

IRENE E. TOYE WARNER.
[Member Société Astro. de France; Brit. Astro. Assoc. etc]

Thou art a lovely mystery, Flaming Star!
Throughout the diamond-pointed glittering sky,
In beds of deepest, purest, sapphire lie
The rolling orbs thou see'st from afar!

O sword of God, thy terrors now are past
No longer quake the nations at thy name,
Though still great awe and wonder doth remain
To see thy fairy beauty fading fast!

Through years thou hast been true to our own Sun
And he has bound thee to his chariot wheel
And made thee some of his attraction feel
And thou shalt follow for all time to come!

Those gauzy phantom, Wanderer of the Night,
Into the dark abyss of space shall go
We cannot see the though thy way we know—
God guides thee on thy trackless path aright!

Halley's comet has come and gone,—has left us to continue its path into the distant regions of the solar system. Many of us who expected to behold a most brilliant fiery object with a tail like a train of light amongst the stars, have perhaps been disappointed. If, however, we regard the late celestial visitor in the proper way our disappointment will I think give place to admiration and awe.

Some things cannot be judged by their mere size or lustre—there are other reasons which have weight, and sentiment plays an important part in our life and our way of regarding many objects of but small intrinsic worth. Does not the dear little daisy of Britain touch the heart of the exile with many tender thoughts which the lovely lily or gorgeous tropical cactus can never stir?

It is just the same with Halley's comet. Ask yourself what changes it has seen in the world's history during the hundreds and perhaps thousands of years that it has traveled through our solar system and visited our Sun! Look back through the ages to the years before history, as we know it, began—before England was inhabited or Ireland arose from her ocean bed, or South Africa was even dreamed of! And remember that this "Rip-van-Winkle" of comets knew our Earth in those days!

Does it not inspire us with awe to know that the seemingly fragile gauzy "star" we have just seen, though but the ghost of its former glorious self, has outlasted the mighty Empires of Babylon, Greece and Rome? In its apparent frailty lies much of the romance and wonder of its history. Punctual to time and place it has come and gone on its long path through space—still the bond-servant of our solar orb though unseen by human eyes!

The northern hemisphere has not been so favored as the southern, for the comet has had to contend with strong twilight, mist, fog, cloud and moonlight. But according to reports other climates and climes have been kinder and in South Africa it has displayed some of its old glory wherewith it terrified our ancestors in the "good old times."

Halley's is in a very special sense our national comet and has witnessed many triumphs of the British arms both on land and sea. Though as a rule regarded as presaging disaster to the world's inhabitants it has not had any direful effect on our country. We can trace the comet back to the year B. C. 467 according to the Chinese records. It is to these people that we owe much for their careful observations on astronomical

events, especially the apparition of a comet.

Halley's comet terrified the Romans in B. C. 12-11, when to them it appeared to be suspended over Rome; and the Jews in A. D. 66 when they were hard pressed by the former at the siege of Jerusalem. It is interesting to know that most probably St. Peter saw the comet at this return, just before his martyrdom. It is also probable that St. Jude refers to it when he says, "Wandering stars, for whom the blackness of darkness is reserved for ever." In the Book of Revelation there are numerous allusions to "signs" of a cometary nature,—"his tail draweth a third part of the stars of heaven."

The two most important dates when the comet was present, that is, as far as our nation is concerned, were 1066 and 1759. The former year made us a nation and the latter an Empire. In 1066 the Normans descended on the shores of England and won the memorable battle of Hastings, and after this date England became of some importance among the European Powers.

In 1456 Halley's comet came amid a scene of great disorder in European affairs. By many people it was indeed regarded as presaging evil to the world. At this time the Mohammedans and Christians were engaged in a deadly struggle for supremacy. So grave was the situation that Pope Calixtus III issued a Crusade Bull on May 15, 1455 in which he urged the Christian leaders to unite against the common enemy. As there has for a long time been an erroneous impression of what this Pope did and said with regard to the comet I will quote the passage in Platinas *vitæ Pontificum* from which the error probably arose. "A hairy and fiery comet having then made its appearance for several days; as the mathematicians declared that there would follow a grievous pestilence, dearth, and some great calamity, Calixtus to avert the wrath of God, ordered supplications that if evil were impending for the human race, He would turn all upon the Turks. He likewise ordered, to move God by continual entreaty, that notice should be given by the bells to all the faithful at mid-day to aid by their prayers those engaged in battle with the Turks." From this simple statement has grown the tale that the Pope "excommunicated" the comet! Belgrade was invested in June 1446 and was just saved by the arrival of the Christian army under Hunyadi, Capistrano, and the Legate Carvajal.

1759 is justly described as one of the most glorious years in our history, "when it was necessary every morning to ask

what new victory there was for fear of missing one"! Though it ended in glory it opened in deepest gloom, we were threatened on all sides by hostile fleets, one at Havre being destined as a menace to the English coast, another at Brest for the invasion of Ireland, another at Dunkirk for the invasion of Scotland, and yet another at Toulon to give help to the other three. At the prospect of war the sea-girt isles of Britain and Ireland proudly faced the foe and put an end to all fear of invasion for many years to come. At the great naval battles of Lagos and Quiberon Bay the French were completely defeated. In India Clive had nearly driven out the French and two years later their rule in that country practically came to an end.

It was the same in North America. Wolfe captured Quebec and Montreal, thus laying the foundation of our Canadian Dominions. Almost every month brought a fresh victory,—Goree was captured in January, Guadaloupe in June, Havre was bombarded by Rodney in July, the battle of Minden was won in August, Lagos and Quebec in September, and Quiberon Bay in November. Cuba also was captured from Spain. 1759 was the first *predicted* return of Halley's comet, 1835 the second, and the one we have just witnessed, the third.

This time it has found yet another colony under the British flag, the great Australian Commonwealth, and an United British South Africa. At the next return it will, I think, see the "Cape to Cairo" railway in full working order.

These are but a few of the many great events this romantic wanderer has witnessed and its story is not yet finished! . . . I will close this article with some verses I wrote after a first glimpse of the comet:—

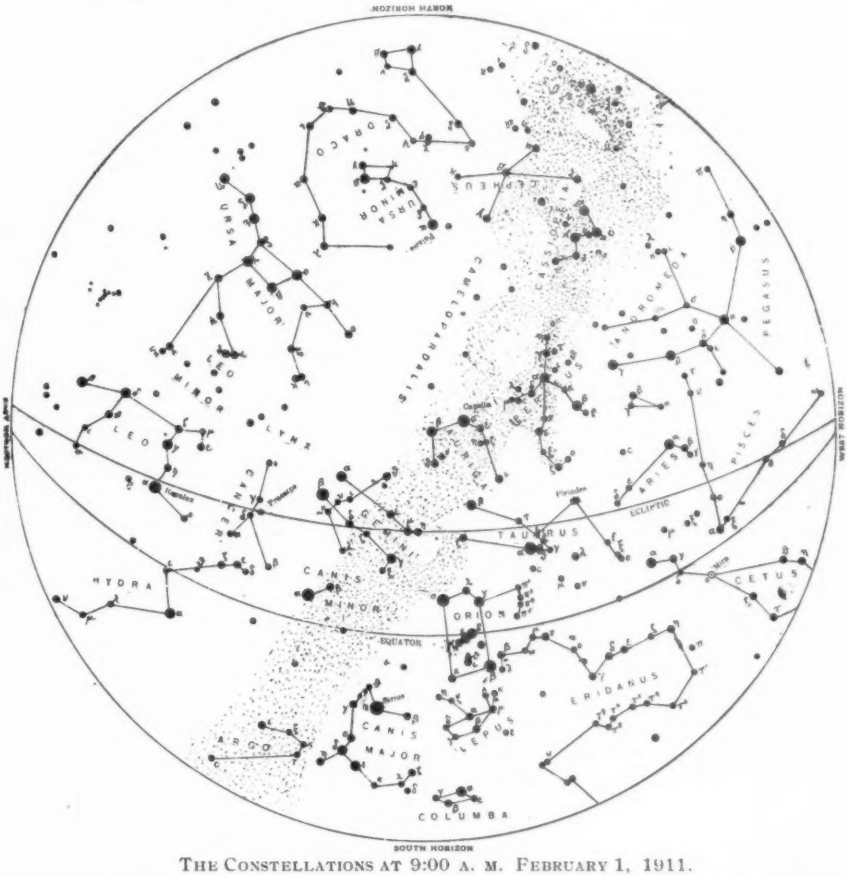
I wonder if in all its wanderings long
Past Planets bright and great,
It heard than Earth's a sadder sweeter song
Burdened with adverse Fate.

At distance vast only Earth's fair form shows—
Hidden the pain and crime:
Only the beauty which the comet knows
Shall live for endless time!

Bristol, England.

PLANET NOTES FOR MARCH, 1911.

Mercury will reach its greatest heliocentric latitude south on March 9. It will then move north and cross the ecliptic on March 28. It will be in superior conjunction on March 19, and will be too close to the Sun throughout the month to be visible.



THE CONSTELLATIONS AT 9:00 A. M. FEBRUARY 1, 1911.

Venus will be in conjunction with the Moon on March 2. It will cross the ecliptic moving north on March 26. It will set from an hour and a half to two hours after the Sun, and will be visible just above the western horizon as an evening star during the month.

Mars will be in conjunction with Uranus on March 10, and with the Moon on March 25. It will rise about three hours before the Sun and will be a morn-

ing star during the month. It is approaching the Earth at present and will be growing brighter.

Jupiter will be in conjunction with the Moon on March 18. It will rise between ten and eleven o'clock during the first part of the month and between eight and nine in the latter part of the month, and will then be a conspicuous object in the sky nearly all night.

Saturn will be in conjunction with the Moon twice during the month, once on March 4 and again on March 31. It will not be in a very good position for observation during the month. It will be in the western sky at sunset during the first of the month and will be lower each day and will be almost lost in the twilight by the end of the month.

Uranus will be in conjunction with the Moon on March 24. Although the planet is considerably west of the Sun it will rise less than an hour before the Sun in the first of the month because it is so far south. During the latter part of the month it may be seen in the southeastern sky just before sunrise.

Neptune will be in conjunction with the Moon on March 9. On March 30 it changes the direction of its motion from west to east. It crosses the meridian shortly after sunset and may be seen with the telescope in the constellation Gemini during the month.

COMET AND ASTEROID NOTES.

Elements and Ephemeris of 1909 HZ (690):—The following elements and ephemeris of 1909 HZ appear in *A. N.* 4463. They were computed by Miss Eleanor Lamson, at the U. S. Naval Observatory, Washington, from observations by Dr. Luther at Düsseldorf.

ELEMENTS.

1909 Dec. 16.5 G. M. T.

M =	26 54 7.3				
ω =	110 56 47.7	1909.0	ω =	110 56 42.7	1911.0
Ω =	254 45 30.1		Ω =	254 47 15.5	
i =	11 11 56.1		i =	11 11 55.9	
ϕ =	10 43 4.7				
μ =	637″.411				
log a =	0.497058				

EPHEMERIS FOR 12h G. M. T.

1911		α app.	δ app.	log Δ
		h m s	° ′ ″	
Jan.	15	8 19 26.4	+7 34 11	0.37188
	19	16 5 5	36 48	37157
	23	12 43.2	40 51	37214
	27	9 22.6	46 12	37360
	31	6 6.6	7 52 44	37595
Feb.	4	2 58.7	8 0 15	37914
	8	8 0 1.4	8 34	38315
	12	7 57 17.3	17 30	38792
	16	7 54 48.9	+8 26 53	0.39337

Magnitude 10.6.

New Elements and Ephemeris of 1910 KU:—The following elements and ephemeris of 1910 KU were computed by Professor V. Cerulli at Rome from his own observations and were published in *A. N.* 4463.

ELEMENTS.

1910 Oct. 25.5 Berlin M. T.

M =	8	58	29.5
ω =	92	23	55.6
Ω =	281	13	15.7
i =	17	17	54.3
ϕ =	8	56	38.3

$\mu = 663''.691$

$\log a = 0.485360$

EPHEMERIS FOR 12h BERLIN M. T.

1911	α h m s	δ ° ′	log Δ
Jan. 9	1 2 12	+ 24 0.0	0.3731
13	6 50	23 52.8	0.3828
17	11 41	23 47.9	0.3924
21	16 45	23 45.1	0.4018
25	1 22 0	23 44.3	0.4110

Magnitude, 9.7.

Second Elements of Comet *e* 1910, (Cerulli-Faye).—In *Lick Bulletin*, No. 187, the following elements of Comet *e* 1910 are published by W. F. Meyer and Sophia H. Levy.

ELEMENTS

T = 1910 Nov. 1.46164 G. M. T.

ω =	199° 17′ 14″.8	1910.0	ω =	199° 17 13.5	1911.0
Ω =	206 14 13 .8		Ω =	206 15 5.3	
i =	10 35 37 .5		i =	10 35 37.1	

$e = 0.565605$

$\mu = 477''.036$

$\log a = 0.580971$

$q = 1.655222$

$P = 7.43800$ years

Elements and Ephemeris of 1909 JB.—Th following elements and ephemeris of 1909 JB. appear in *A. J.* No. 621. They were computed by Mr. Alfred Davis, at the University of Minnesota, from observations by Rev. Joel H. Metcalf and Professor Everett I. Yowell.

ELEMENTS.

1909 Nov. 7.5, G. M. T.

M =	47°	14′	8″
ω =	77	45	11
i =	13	55	42
Ω =	275	38	14
ϕ =	8	56	35

1909.0

$\mu = 877''.30$

$\log a = 0.040457$

RESIDUALS (O—C

		Δα s	Δδ ″
1909	Nov. 7	−0.2	−0.5
	30	+0.1	−2.3
	Dec. 4	+0.2	−1.6
	9	−0.1	+0.6
1910	Jan. 8	−0.1	+0.6

EPHEMERIS 12h G. M. T.

1911	α (1911.0) h m s	δ (1911.0) ° ′ ″	log Δ
Jan. 29	10 48 00	−10 36 13	0.32158
Feb. 2	45 18	45 6	31525
6	42 19	50 16	30961
10	39 4	52 9	30472
14	35 36	50 35	30066
18	31 58	45 36	29749
22	28 14	37 18	29526
26	24 28	25 39	29402
Mar. 2	20 42	11 28	29378
6	10 17 1	10 54 32	
10	13 26	9 35 26	29630
14	10 9	14 35	29900
18	7 4	8 52 24	30261
22	4 16	29 19	30708
26	1 47	5 44	31231
30	9 59 40	7 42 5	31838
Apr. 3	9 57 55	7 18 45	0.32483

VARIABLE STARS.

Nova Lacertae.—Dyson telegraphs "Espin telegraphs new star eighth magnitude twenty-two hours thirty-two minutes fifty-two degrees fiifteen north two bright lines."

Note: This object which will be designated as Nova Lacertae, was observed last night visually and photographically, at the Harvard College Observatory. The collection of photographs shows that it was invisible November 17, 1910, but appeared on November 23 and December 7. It was then equal to H. R. 8613 = 9 Lacertae, photographic magnitude 5.00. Its photographic magnitude last night was about 7.0. It does not appear on several early photographs, the first taken on December 1, 1887, showing very faint stars. Photographs of the spectrum by Mr. E. S. King showed eleven bright lines.

From photometric measures by Professor O. C. Wendell the Nova appears to be 1.30 magnitude brighter than + 51° 3420 magn. 8.7. Observations by Mr. L. Campbell with Argelander's method make the photometric magnitude of the Nova 7.1. It is visible in an opera glass.

EDWARD C. PICKERING.

Harvard Astronomical Bulletin, No. 439. Dec. 31, 1910.

NOVA LACERTÆ OF 1910.

Observations made at the Yerkes Observatory.

December 31, 1910.

40-inch telescope. Visual estimates by several observers make brightness about 1¾ magnitudes greater than that of B. D. +51°.3420.

"Parallax plate" of field taken by Slocum.

Visual observation with ocular spectroscope by Frost and others indicate typical spectrum of Nova. Hα especially brilliant, glowing like a live coal

Zeiss U. V. doublet and objective-prism. Three good plates of spectrum obtained by Parkhurst and Gingrich. Scale very small. Fifteen bright lines visible. Measures by Frost show hydrogen lines, β to ϵ, very bright; also some dark lines.

Bruce photographic telescope. Plates of the field obtained by Barnard in poor sky.

January 2, 1911.

Zeiss U. V. doublet. Focal and extra-focal plates secured by Parkhurst for photometric determinations. Atmospheric conditions very poor.

January 3.

Sky very transparent, temperature about 0° F.

40-inch telescope. Excellent plate obtained by Frost with the Bruce spectrograph, with exposure of two hours. The bright lines seen with low dispersion are shown to be complex and very broad, those of hydrogen being between 35 and 40 tenth-meters wide. Bright maxima of intensity have very large displacements towards the red, indicative of high pressure (or of velocity of recession of some 600 km per second, this improbable). Several dark lines or reversals can also be seen within the broad bright bands. The broadest bright band, having few maxima (perhaps only a maximum) of intensity, extends from about λ 4580 to about λ 4710, with strongest part at about λ 4640.

This spectrum is very similar to that observed in case of Nova *Aurigae* and Nova *Persei*, at corresponding stages of progress.

Visual observations by Barnard. In the principal focus of the 40-inch the Nova was of a whitish color with crimson glow about it. The image when sharp agreed essentially with that of an ordinary star. 8.9 mm. farther away from the object glass is formed a beautiful crimson image of the star, as sharp as the other image. The star is there surrounded with a greenish gray halo. This appearance is quite the same as that observed in the case of Nova *Geminorum* (1903), and it is of course due to the concentration of crimson light in the α line of hydrogen.

The position of the star was accurately referred to B. D. +51°.3420 (Cambridge U. S., A. G. 7788), and is as follows:

1911.0 $\alpha = 22^h\ 32^m\ 11^s.79$; $\delta = +52°\ 15'\ 19''.8$

Professor Barnard finds a star in the exact position of the Nova on three plates taken by him with the 10-inch and 6-inch lenses of the Bruce telescope, as follows:

1907 August 7	Exposure	$0^h\ 47^m$
1909 August 22		5 55
1909 August 24		3 55

The approximate magnitude of the star on these plates is 14. He also finds the star on a plate taken by him with the Willard lens of the Lick Observatory on 1893, October 11. Exposure 6h 21m.

2-foot reflector. A photograph of the field of the Nova was taken with

the two-foot reflector by Parkhurst and Slocum with an exposure of two hours. The quality of the plate was not such as to be decisive, but the presence of some nebulosity around the Nova was strongly suggested.

Zeiss U. V. camera. (Observations by Parkhurst.)

1911 January 7, Parallax plate taken by Slocum.

1911 January 17.

The spectrogram shows some change from that taken December 31. The more refrangible rays have increased in intensity relative to Hβ and the band at λ 4640. The hydrogen lines are distinctly double, the less refrangible components being more intense. The centers of the the components of Hγ and Hδ are separated by about 25 tenth-meters, corresponding to the very improbable relative velocity of between 1700 and 1800 km per second. The separation of the fainter lines is similar in amount, but not so easy to measure.

Photometric observations.

The brightness of the Nova has been determined by Parkhurst on five plates, focal and extra-focal, taken with the Zeiss doublet, as follows:

	G.M.T.		
1911 January	2.61	7.12	.....
	2.64	.....	7.4
	3.56	7.21	7.5
	6.59	.....	7.75

EDWIN B. FROST.

Yerkes Observatory, Jan. 19, 1911.

The Designation of Recently Discovered Variable Stars.— The following list of variable stars discovered since the latter part of 1908, was published in *A.N.* No. 4457. It is reproduced here for the benefit of those of our readers who are interested in the study of variable stars and who may not have access to the *Astronomische Nachrichten*.

No.	Prov. No. A. N.	Name	Position 1900 R. A. h	m	s	Decl. °	′	Magnitude Max. m	Min m_1
1	31.1910	UU Andromedae	0	38	31	+ 30	24	10.7	11.9
2	29.1910	TX Andromedae	1	16	11	+ 38	10	10.7	12.0
3	30.1910	UV Andromedae	1	23	34	+ 36	8	11.3	12.0
4	44.1910	TT Persei	1	44	0	+ 53	14.8	8.9	10.5
5	147.1907	V Arietis	2	9	37	+ 11	46.3	8.3	9.0
6	144.1908	V Horologii	3	1	0	− 59	19.4	7.0	9.3
7	20.1909	TU Persei	3	1	49	+ 52	48.6	11.4	12.2
8	45.1910	SS Cephei	3	33	48	+ 80	0.3	7.7	9.0
9	4.1908	TV Aurigae	4	50	35	+ 48	23.6	8.6	9.9
10	173.1908	TY Aurigae	4	51	26	+ 48	8.6	9	<12.5
11	46.1910	TX Aurigae	5	2	13	+ 38	52.3	8.7	10.6
12	47.1910	RT Orionis	5	27	50	+ 7	4.9	8.7	10.6
13	49.1908	TW Aurigae	5	49	44	+ 45	29.7	8.4	9.3
14	51.1908	SV Geminorum	5	54	33	+ 24	28.1	9.8	<11.0
15	145.1908	T Volantis	6	57	47	− 66	59.0	9.1	14.1
16	18.1909	TZ Aurigae	7	4	37	+ 40	56	10	11
17	5.1908	SU Ursae Majoris	8	3	22	+ 62	54	11.5	<12.5
18	24.1909	RZ Velorum	8	33	35	− 43	45.9	7.5	8.6
19	30.1909	RV Velorum	9	15	39	− 50	8.7	9.9	11.9
20	31.1909	RW Velorum	9	16	53	− 49	6.0	8.5	11.0
21	32.1909	RX Velorum	9	24	7	− 50	38.0	8.8	10.5
22	35.1909	SV Carinae	9	45	18	− 59	4.2	10.0	<13.5

No.	Prov. No. A. N.	Name	Position 1900 R. A. h	m	s	Decl. °	′	Magnitude Max. m	Min. m
23	48.1910	SZ Carinae	9	56	42	−59	44.3	8.6	10.1
24	38.1909	SU Carinae	10	10	11	−60	23.3	10.0	<15.5
25	39.1909	RY Velorum	10	16	56	−54	49.1	8.0	10.0
26	41.1909	SW Carinae	10	23	17	−57	45.9	9.3	<12
27	146.1908	RT Velorum	10	26	0	−46	12	10.5	<12.0
28	7.1910	SV Ursae Majoris	10	40	22	+55	33.7	8.2	9.7
29	42.1909	SX Carinae	10	42	7	−57	1.3	8.3	10.0
30	147.1908	RU Velorum	10	49	25	−52	39.6	10.7	15.3
31	148.1908	SY Carinae	11	11	15	−57	23.0	8.8	10.0
32	43.1906	S Crateris	11	47	39	−7	2.4	8.4	9.5
33	49.1910	TV Centauri	12	9	16	−50	58.8	9.3	10.8
34	—	60 B. Canum Ven.	12	40	26	+45	59.2	5.2	6.0
35	50.1910	U Canum Ven	12	42	36	+38	55	8.0	<12.5
36	51.1910	RW Hydrae	13	28	47	−24	52.0	8.1	9.6
37	53.1910	TW Centauri	13	51	57	−30	34.5	7.6	14.0
38	54.1910	TX Centauri	14	27	36	−60	33	10.8	13.3
39	149.1908	Z Lupi	14	29	27	−42	55.8	8.2	9.6
40	55.1910	RV Bootis	14	35	3	+32	58.2	8.2	10.0
41	56.1910	RW Bootis	14	36	59	+32	0.0	7.5	9.8
42	57.1910	U Apodis	15	16	8	−75	34.5	10.2	<11.8
43	150.1908	RW Librae	15	17	14	−23	42.4	8.6	11.7
44	88.1910	TW Draconis	15	32	24	+64	14.4	7.0	8.9
45	151.1908	RX Librae	15	36.2		−20	26	10.3	<11.3
46	173.1907	RS Coronae	15	54	48	+36	18.5	9.6	10.6
47	152.1908	X Arae	16	28.8		−55	12	9.4	14.5
48	153.1908	Y Arae	16	30	25	−59	36.2	9.1	<12.8
49	154.1908	W TrianguliAustr.	16	41.6		−67	48	9.4	12.5
50	155.1908	Z Arae	16	46.0		−56	6	9.3	13.5
51	59.1910	SY Ophiuchi	16	49	8	−21	48.3	8.4	9.6
52	156.1908	SZ Scorpii	16	49	38	−39	28.4	9.0	<13.5
53	176.1907	TT Herculis	16	49	55	+17	0.1	8.9	9.5
54	60.1910	TU Scorpii	17	1	6	−31	42	9.3	12.9
55	157.1908	TV Draconis	17	7	49	+64	26.6	8.8	10.0
56	61.1910	SZ Ophiuchi	17	9	38	−7	56.6	9.5	21.5
57	37.1910	TU Herculis	17	9	46	+30	50.0	9.5	12
58	158.1908	TT Draconis	17	11	14	+57	58.7	8.1	9.7
59	91.1910	TX Herculis	17	15	27	+41	59.5	8.0	8.9
60	62.1910	RR Arae	17	20	6	−49	49	10.7	<13.2
61	159.1908	TT Scorpii	17	33	25	−41	34.5	11.4	13.4
62	63.1910	TV Scorpii	17	36	10	−43	43.2	11.1	12.8
63	93.1910	TW Herculis	17	50	42	+30	25.8	9.5	11.0
64	64.1910	RR Coronae Austr.	17	59	0	−38	15	10.0	<12.3
65	36.1910	TV Herculis	18	10	56	+31	48	9	11
66	8.1910	RS Telescopii	18	11	22	−46	35.3	9.5	<12.0
67	50.1901	Z Coronae Austr	18	23	41	−45	4.1	11.0	<12.9
68	65.1910	RX Scuti	18	31	39	−7	41.2	9.7	12·0
69	27.1910	RR Scuti	18	35	39	−4	10.6	8	9
70	66.1910	RT Telescopii	18	36	29	−47	20.8	9.6	10.8
71	59.1907	RU Scuti	18	36	40	−4	12 4	9.1	10.2
72	161.1908	RV Scuti	18	38	47	−13	19.4	8.6	10.1
73	62.1907	RS Scuti	18	43	40	−10	21.0	9.3	10.3
74	26.1910	RT Scuti	18	44	5	−10	30.0	9.1	9.7
75	42.1910	TU Draconis	18	48	53	+48	47	10	<12
76	67.1910	UX Sagittarii	18	49	8	−16	39.0	8.1	9.0
77	162.1908	RW Scuti	18	51	0	−10	39.3	8.3	9.7
78	9.1910	RS Coronae Austr	18	56	20	−39	42.6	10.0	<13 0
79	68.1810	RU Telescopii	19	0	35	−48	24.4	9.3	14.9
80	9.1909	TW Sagittarii	19	7	30	−21	45	8.2	<11.5
81	10.1909	TX Sagittarii	19	8	12	−17	36	9.2	<11.7
82	119.1907	SZ Draconis	19	9	42	+65	56.1	8.9	9.8
83	32.1910	TY Aquilae	19	9	45	−7	11.0	10	11

No.	Prov. No. A. N.	Name	Position 1800 R. A. h	m	s	Decl. °	′	Magnitude Max. m	Min. m
84	164.1908	TY Sagittarii	19	11	39	− 4	6.3	8.5	<13.8
85	10.1910	TZ Sagittarii	19	13	9	− 40	23.0	10.0	<13.0
86	16.1908	RS Vulpeculae	19	13	25	+ 22	15.7	6.9	8.0
87	11.1910	UU Sagittarii	19	17	50	− 39	26.8	10.0	<13.0
88	12.1910	TU Sagittarii	19	19	37	− 35	32.8	9.5	12.2
89	13.1910	TU Aquilae	19	22	33	+ 1	51.0	9.8	<13.5
90	14.1910	UV Sagittarii	19	22	43	− 38	17.5	10.0	<13.0
91	69.1910	Z Pavonis	19	26	20	− 62	58.4	8.7	10.4
92	70.1910	AF Cygni	19	27	13	+ 45	56.3	7.3	9 0
93	15.1910	Z Telescopii	19	32	22	− 45	48.3	9.2	<13.5
94	16.1910	TV Sagittarii	19	37	16	− 42	5.4	9.0	13.2
95	71.1910	UW Sagittarii	19	40	39	− 18	23.7	8.4	10.2
96	17.1910	TW Aquilae	19	46	24	+ 13	42.6	10.6	12.7
97	166.1908	RR Telescopii	19	56.3		− 56	0	9.0	<11.5
98	72.1910	RR Pavonis	19	57	42	− 63	42	8.9	<12.2
99	18.1910	TX Aquilae	20	1	38	+ 3	34.4	9.0	10.8
100	19.1910	TV Aquilae	20	7	58	+ 6	0.1	10.0	13.9
101	20.1910	RX Capricorni	20	9	21	− 13	15.1	9.6	<11.0
102	21.1910	RW Capricorni	20	12	14	− 17	59.3	8.8	10.6
103	73.1910	TZ Aquilae	20	25	2	− 5	5.3	9.6	10.5
104	161.1907	AD Cygni	20	27	37	+ 32	13.6	9.2	9.7
105	74.1910	U Indi	20	35	3	− 51	26.7	9.5	10.9
106	23.1910	V Indi	21	4	51	− 45	29.0	7.9	9.5
107	75.1910	W Indi	21	7	12	− 53	26	8.6	11.0
108	28.1910	AE Cygni	21	9	0	+ 30	19.6	10.8	11.4
109	167.1908	Y Pavonis	21	15	13	− 70	9.5	5.7	8.5
110	76.1910	W Microscopii	21	16	35	− 42	23.5	10.3	<13.5
111	22.1909	SW Pegasi	21	17	58	+ 21	34	9.5	<10.5
112	77.1910	X Indi	21	23	24	− 54	24	8.1	<11.9
113	78.1910	Y Indi	21	37	6	− 53	11	9.5	12.9
114	24.1910	Z Indi	21	47	51	− 50	24.8	10.3	11.6
115	169.1908	U Piscis Austr.	21	56.8		− 28	21	10.8	12.1
116	170.1908	V Octanis	21	58.8		− 75	16	8.0	11.0
117	162.1907	SV Pegasi	22	1	21	+ 34	51.7	8.4	9.0
118	1.1910	SY Pegasi	22	1	26	+ 34	25.1	9.0	<10
119	2.1910	SZ Pegasi	22	2	7	+ 34	57.9	8.9	9.6
120	25.1910	ST Cephei	22	26	23	+ 56	29.3	9.2	10.8
121	15.1909	RV Lacertae	22	40	21	+ 49	13	10	11
122	34.1910	RW Lacertae	22	40	36	+ 49	8.2	10.2	11.2
123	46.1909	SX Pegasi	22	45	26	+ 17	22	9.2	9.9
124	79.1910	TY Andromedae	23	10	0	+ 40	15.0	8.5	10.0
125	80.1910	TZ Andromedae	23	45	52	+ 46	57.1	7.2	8.7
126	21.1909	TW Andromedae	23	58	10	+ 32	17.3	8.6	11.5

Approximate Magnitudes of Variable Stars on Jan. 1, 1911.

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Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn
χ Androm.	0	10.8	+46	27	13.2	W Cassiop.	0	49.0	+58	1	8.8 *i*
T Androm.		17.2	+26	26	13.0	U Androm.	1	9.8	+40	11	<13
T Cassiop.		17.8	+55	14	10.4*i*	S Cassiop.		12.3	+72	5	13.5*d*
R Androm.		18.8	+38	1	8.2*d*	RU Androm.		32.8	+38	10	13.0
S Ceti		19.0	− 9	53	12.0*d*	Y Androm.		33.7	+38	50	9.0 *i*
YCephei		31.3	+79	48	13.5*d*	X Cassiop.		49.8	+58	46	11.0
U Cassiop.		40.8	+47	43	<14	U Persei		53.0	+54	20	8.4
RW Androm.		41.9	+32	8	9.5*d*	R Arietis	2	10.4	+24	35	11.0 *i*
RR Androm.		45.9	+33	50	<13	W Androm.		11.2	+43	50	9.5*d*
RV Cassiop.		47.1	+46	53	14.2	Z Cephei		12.8	+81	13	12.5*d*

Approximate Magnitudes of Variable Stars on Jan. 1, 1911—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
o Ceti	2	14.3	− 3	26	8.2*d*	R Leo. Min.	9	9.6	+34	58	7.1
R Ceti		20.9	− 0	38	9.8 *i*	RR Hydrae		40.4	−23	34	13.4
RR Persei		21.7	+50	49	13.8 *i*	R Leonis		42.2	+11	54	9.0
RR Cephei		30.4	+80	42	11.6*d*	Y Hydrae		46.4	−22	33	6.8
R Trianguli		31.0	+33	50	7.5 *i*	V Leonis		54.5	+21	44	13.0
U Arietis	3	5.4	+14	25	<14	R Urs. Maj.	10	37.6	+69	18	9.8
X Ceti		14.3	− 1	26	10.0 *i*	W Leonis		48.4	+14	15	<14
Y Persei		20.9	+43	50	9.6	V Hydrae		46.8	−20	43	8.0
R Persei		23.7	+35	20	13.0	S Leonis	11	5.7	+ 6	0	12.8
R Tauri	4	22.8	+ 9	56	10.0	R Comae Ber.		59.1	+19	20	13.0
W Tauri		22.2	+15	49	10.2 *i*	T Can. Ven.	12	25.2	+32	3	9.4
T Camelop.		30.4	+65	57	9.0 *i*	T Urs. Maj.		31.8	+60	2	9.9*d*
X Camelop.		32.6	+74	56	12.0	R Virginis		33.4	+ 7	32	7.4*d*
RX Tauri		32.8	+ 8	9	<14	RS Urs. Maj.		34.4	+59	2	8.6
R Leporis		55.0	−14	57	6.6	S Urs. Maj.		39.6	+61	38	9.4 *i*
V Orionis	5	0.8	+ 3	58	11.0*d*	RU Virginis		42.2	+ 4	42	9.0
T Leporis		0.6	−22	2	9.8*d*	U Virginis		46.0	+ 6	6	12.7
R Aurigae		9.2	+53	28	13.0*d*	T Urs.Min.	13	32.6	+73	56	13.4*d*
S Aurigae		20.5	+34	4	9.6	R Can. Ven.		44.6	+40	2	10.6*d*
W Aurigae		20.1	+36	49	10.9 *i*	Z Bootis	14	1.7	+13	59	<13.5
S Orionis		24.1	− 4	46	8.5 *i*	S Bootis		19.5	+54	16	12.6
S Camelop.		30.2	+68	45	9.2 *i*	V Bootis		25.7	+39	18	7.8*d*
U Aurigae		35.6	+31	59	12.5*d*	R Camelop.		25.1	+84	17	9.4 *i*
Z Tauri		46.7	+15	46	13.8	R Bootis		32.8	+27	10	8.0 *i*
U Orionis		49.9	+20	10	9.8*d*	S Coronae	15	17.3	+31	44	11.4 *i*
V Camelop.		49.4	+74	30	13.5*d*	S Urs.Min.		33.4	+78	58	8.8 *i*
SU Tauri		43.2	+19	2	12.2 *i*	R Coronae		44.4	+28	28	9.6 *i*
X Aurigae	6	4.4	+50	15	8.0 *i*	RU Herculis	16	6.0	+25	20	12.5
SS Aurigae		5.8	+47	46	10.8	W Herculis		31.7	+37	32	8.0
V Monoc.		17.7	− 2	9	12.5*d*	R Draconis		32.4	+66	58	8.2
S Lyncis		35.9	+58	0	9.5 *i*	V Draconis	17	56.3	+54	53	<13
U Lyncis		31.8	+59	57	12.6	T Herculis	18	5.3	+31	0	11.0 *i*
X Gemin.		40.7	+30	23	12.5	X Draconis		6.8	+66	8	13.0*d*
W Monoc.		47.5	− 7	2	10.4	W Draconis		5.4	+65	56	10.4 *i*
Y Monoc.		51.3	+11	22	9.8	W Lyrae		11.5	+36	38	12.0*d*
X Monoc.		52.4	− 8	56	9.8	RY Lyrae		41.2	+34	34	13.0*d*
R Lyncis		53.0	+55	28	9.0	Z Lyrae		56.0	+34	49	9.6 *i*
RS Gemin.		55.2	+30	40	11.8	V Lyrae	19	5.2	+29	30	<13.5
V Can. Min.	7	1.5	+ 9	2	11.7	S Lyrae		9.1	+25	50	14.0
R Gemin.		1.3	+22	52	11.2	RS Lyrae		9.3	+33	15	<13
R Can. Min.		3.2	+10	11	7.8	RU Lyrae		9.1	+41	8	12.8*d*
RR Monoc.		12.4	+ 1	17	11.5*d*	U Draconis		9.9	+67	7	10.0
V Gemin.		17.6	+13	17	13.0	R Cygni		34.1	+49	58	9.6*d*
S Can. Min.		27.3	+ 8	32	12.0	RT Cygni		40.8	+48	32	10.6 *i*
T Can. Min.		28.4	+11	58	<13	TU Cygni		43.3	+48	49	10.5 *i*
Z Puppis		28.3	−20	27	<13	χ Cygni		46.7	+32	40	11.8*d*
U Can. Min.		35.9	+ 8	37	12.8	Z Cygni		58.6	+49	46	9.4*d*
T Gemin.		43.3	+23	59	11.0	S Cygni	20	3.4	+57	42	<14
U Gemin.		49.2	+22	16	9.4	S Aquilae		7.0	+15	19	12.0
U Puppis		56.1	−12	34	<14	RS Cygni		9.8	+38	28	9.0*d*
R Cancri	8	11.0	+12	2	9.4	R Delphini		10.1	+ 8	47	12.8*d*
V Cancri		16.0	+17	36	8.9	SX Cygni		11.6	+30	46	10.4*d*
RT Hydrae		24.7	− 5	59	9.0	U Cygni		16.5	+47	35	7.8*d*
U Cancri		30.0	+19	14	11.2	Z Delphini		28.1	+17	7	14.0*d*
S Hydrae		48.4	+ 3	27	8.0	ST Cygni		29.9	+54	38	13.5
T Hydrae		50.8	− 8	46	11.9	Y Delphini		36.9	+11	31	11.4 *i*
T Cancri		51.0	+20	14	8.7	S Delphini		38.5	+16	44	10.2
W Cancri	9	4.0	+25	39	12.8	Y Aquarii		39.2	− 5	12	12.0
X Hydrae		30.7	−14	15	11.2	T Delphini		40.7	+16	2	13.0
Y Draconis		31.1	+78	18	12.7	V Delphini		43.5	+18	58	<14

Approximate Magnitudes of Variable Stars on Jan. 1, 1911—Con.

Name.	h	R. A. 1900. m	Decl. 1900. ° ′	Magn.	Name.	h	R. A. 1900. m	Decl. 1900. ° ′	Magn.
T Aquarii		44.7	− 5 31	12.0*d*	S Aquarii		51.8	−20 53	13.4*d*
RZ Cygni		48.5	+46 59	13.0*d*	RW Pegasi		59.2	+14 46	11.5*d*
R Vulpeculae		59.9	+23 26	9.0 *i*	R Pegasi	23	1.6	+10 0	9.6*d*
TW Cygni	21	1.8	+29 0	11.4*d*	V Cassiop.		7.4	+59 8	7.8
X Cephei		3.6	+82 40	<13	W Pegasi		14.8	+25 44	10.4*d*
R Equulei		8.4	+12 23	12.0*d*	S Pegasi		15.5	+ 8 22	10.0 *i*
T Cephei		8.2	+68 5	10.0*d*	R Aquarii		38.6	−15 50	10.0
S Cephei		36.5	+78 10	8.6*d*	Z Cassiop.		39.7	+56 2	<13
T Pegasi	22	4.0	+12 3	11.0 *i*	RR Cassiop.		50.7	+53 8	11.4*d*
Y Pegasi		6.8	+13 52	12.0 *i*	V Ceti		52.8	− 9 31	8.8 *i*
RS Pegasi		7.4	+14 4	12.4	R Cassiop.		53.3	+50 50	11.0 *i*
RV Pegasi		21.0	+29 58	10.0 *i*	Z Pegasi		55.0	+25 21	11.5*d*
S Lacertae		24.6	+39 48	8.8 *i*	Y Cassiop.		58.2	+55 7	10.0
R Lacertae		38.8	+41 51	9.2 *i*					

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Vassar, Mt. Holyoke, Amherst, Olcott, Jacobs, Hunter and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours, etc. For stars marked with an * alternate minima are given; ** every third minimum; † every tenth minimum.]

SY Androm.

d	h
Mar. 27	0

*U Cephei

d	h
Mar. 2	7
7	7
12	6
17	6
22	6
27	5

*Z Persei

d	h
Mar. 3	19
9	21
16	0
22	3
28	5

RY Persei

d	h
Mar. 6	3
12	23
19	20
26	17

**RZ Cassiop.

d	h
Mar. 3	7
6	21
10	11
14	2
17	16
21	6
24	20
28	10
31	23

*ST Persei

d	h
Mar. 5	22
11	6
16	13
21	20
27	3

RX Cephei

d	h
Mar. 30	22

*Algol

d	h
Mar. 5	17
11	10
17	4
22	22
28	15

**RT Persei

d	h
Mar. 3	6
5	19
8	9
10	22
13	11
16	0
18	13
21	2
23	16
26	5
28	18
31	7

λ Tauri

d	h
Mar. 3	10
7	9
11	8
15	6
19	5
23	4
27	3
31	2

*RW Tauri

d	h
Mar. 4	15
10	4
15	17
21	6
26	19

*RV Persei

d	h
Mar. 1	5
5	4
9	3
13	1
17	0
20	23
24	22
28	20

RW Persei

d	h
Mar. 11	9
24	14

RS Cephei

d	h
Mar. 6	20
19	6
31	16

*RY Aurigae

d	h
Mar. 2	11
7	22
13	9
18	20
24	7
29	18

*RZ Aurigæ

d	h
Mar. 3	1
9	2
15	2
21	3
27	4

51.1908 Gemin.

d	h
Mar. 3	5
7	6
11	6
15	6
19	6
23	6
27	6
31	7

*RW Gemin.

d	h
Mar. 6	3
11	21
17	15
23	8
29	2

*U Columbæ

d	h
Mar. 4	15
10	5
15	19
21	10
27	0

*RW Monoc.

d	h
Mar. 4	16
8	12
12	7
16	3
19	22
23	18
27	13
31	9

RX Gemin.

d	h
Mar. 9	12
21	17

**RU Monoc.

d	h
Mar. 1	16
4	9
7	1
9	18
12	10
15	3
17	19
20	12
23	4
25	21
28	13
31	6

Minima of Variable Stars of the Algol Type.—Continued.

**R Canis Maj.

	d	h
Mar.	3	21
	7	7
	10	17
	14	3
	17	13
	20	22
	24	8
	27	18
	31	4

RY Geminorum

Mar.	7	12
	16	19
	26	2

*Y Camelop.

Mar.	3	14
	10	4
	16	19
	23	10
	30	0

RR Puppis

Mar.	2	14
	9	0
	15	10
	21	21
	28	7

**V Puppis

Mar.	3	13
	7	22
	12	7
	16	16
	21	0
	25	9
	29	18

†X Carinæ

Mar.	2	8
	7	18
	13	4
	18	13
	23	23
	29	9

S Cancri

Mar.	1	5
	10	17
	20	4
	29	16

S Velorum

Mar.	1	13
	7	11
	13	9
	19	8
	25	6
	31	5

**Y Leonis

Mar.	3	21
	8	23
	14	0
	19	2
	24	3
	29	5

**RR Velorum

	d	h
Mar.	3	6
	8	20
	14	9
	19	23
	25	12
	31	2

*SS Carinae

Mar.	2	6
	8	21
	15	11
	22	2
	28	16

RW Urs. Maj.

Mar.	1	10
	8	18
	16	2
	23	9
	30	17

**Z Draconis

Mar.	3	22
	8	0
	12	1
	16	3
	20	5
	24	7
	28	8

*SS Centauri

Mar.	3	17
	8	16
	13	15
	18	14
	23	13
	28	12

*δ Libræ

Mar.	4	16
	9	7
	13	23
	18	15
	23	7
	27	22

*U Coronæ

Mar.	6	10
	13	7
	20	5
	27	3

*SW Ophiuchi

Mar.	2	4
	7	2
	11	23
	16	20
	21	18
	26	15
	31	13

*SX Ophiuchi

Mar.	4	21
	9	0
	13	3
	17	6
	21	9

*SX Ophiuchi

	d	h
Mar.	25	12
	29	15

R Aræ

Mar.	4	20
	9	6
	13	16
	18	2
	22	13
	26	23
	31	9

**U Ophiuchi

Mar.	2	13
	5	1
	7	14
	10	2
	12	14
	15	3
	17	15
	20	4
	22	16
	25	4
	27	17
	30	5

**SZ Herculis

Mar.	1	8
	3	19
	6	6
	8	17
	11	4
	13	15
	16	2
	18	12
	20	23
	23	10
	25	21
	28	8
	30	19

Z Herculis

Mar.	3	11
	7	10
	11	10
	15	10
	19	10
	23	10
	27	10
	31	9

SX Draconis

Mar.	1	17
	6	21
	12	1
	17	6
	22	10
	27	15

*RS Sagittarii

Mar.	2	9
	7	5
	12	1
	16	21

*RS Sagittarii

	d	h
Mar.	21	17
	26	12
	31	8

*V Serpentis

Mar.	6	14
	13	12
	20	10
	27	8

†RZ Draconis

Mar.	2	22
	8	10
	13	23
	19	11
	24	23
	30	11

** RX Herculis

Mar.	1	11
	4	3
	6	19
	9	11
	12	3
	14	19
	17	11
	20	3
	22	19
	25	11
	28	3
	30	19

*SX Sagittarii

Mar.	5	1
	9	5
	13	9
	17	12
	21	16
	25	20
	29	23

*RR Draconis

Mar.	5	21
	11	13
	17	5
	22	20
	28	12

**U Scuti

Mar.	3	2
	5	23
	8	20
	11	16
	14	13
	17	10
	20	7
	23	3
	26	0
	28	21
	31	18

*RX Draconis

	d	h
Mar.	3	1
	6	20
	10	15
	14	10
	18	5
	22	0
	25	18
	29	13

*RV Lyræ

Mar.	2	20
	10	1
	17	6
	24	11
	31	16

16.1908 Vulpec.

Mar.	1	14
	6	1
	10	13
	15	0
	19	11
	23	23
	28	10

*U Sagittae

Mar.	5	7
	12	2
	18	20
	25	14

Z Vulpeculæ

Mar.	1	21
	6	18
	11	16
	16	14
	21	12
	26	10
	31	8

SY Cygni

Mar.	5	10
	11	10
	17	10
	23	11
	29	11

*WW Cygni

Mar.	2	0
	8	15
	15	7
	21	22
	28	13

SW Cygni

Mar.	3	7
	7	21
	12	11
	17	1
	21	14
	26	4
	30	18

Minima of Variable Stars of the Algol Type.—Continued.

VW Cygni		RR Delphini		**VV Cygni		**28.1910Cygni		*TT Androm.	
d	h	d	h	d	h	d	h	d	h
Mar. 9	10	Mar. 2	16	Mar. 4	15	Mar. 17	2	Mar. 4	23
17	20	7	6	9	2	29	0	10	11
26	6	11	21	13	12	22	21	16	0
*UW Cygni		16	11	17	22	25	19	21	13
Mar. 7	12	21	1	22	9	28	17	27	1
14	9	25	16	26	19	31	15		
21	7	30	6	31	5	WZ Cygni		21.1909 Andr.	
28	5					Mar. 28	12	Mar. 2	7
W Delphini		RR Vulpeculae		**28.1910Cygni		*RT Lacertae		6	10
Mar. 5	13	Mar. 4	10	Mar. 2	13	Mar. 3	21	10	12
10	8	9	11	5	11	8	23	14	15
15	3	14	13	8	9	14	0	18	18
19	23	19	14	11	6	19	2	22	21
24	18	24	15	14	4	24	4	27	0
29	14	29	16			29	6	31	2

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SX Cassiop.		SX Aurigae		RZ Geminorum		T Velorum		RZ Centauri	
d	h	d	h	d	h	d	h	d	h
Mar. 22	13	Mar. 1	1	Mar. 5	15	Mar. 4	15	Mar. 1	10
SY Cassiop.		2	12	11	3	9	6	2	9
Mar. 4	6	4	3	16	16	13	22	3	7
8	8	5	15	22	4	18	13	4	6
12	9	7	4	27	16	23	5	5	4
16	11	8	17	RS Orionis		27	20	6	3
20	13	10	6	Mar. 1	9	W Carinæ		7	1
24	14	11	18	8	22	Mar. 3	17	7	23
28	16	13	7	16	12	8	1	8	22
RW Cassiop.		14	20	24	1	12	10	9	21
Mar. 8	22	16	9	31	14	16	19	10	19
23	17	17	21	T Monoc.		21	4	11	18
SU Cassiop.		19	10	Mar. 17	22	25	13	12	16
Mar. 1	22	20	23	W Geminorum		29	22	13	15
3	21	22	12	Mar. 4	11	S Muscæ		14	13
5	20	24	0	12	9	Mar. 8	10	15	12
7	18	25	13	20	7	18	2	16	10
9	17	27	2	28	5	27	18	17	9
11	16	28	15	ζ Geminorum		T Crucis		18	7
13	15	30	3	Mar. 2	18	Mar. 5	7	19	6
15	14	31	16	12	19	12	1	20	4
17	12	SY Aurigae		22	23	18	18	21	3
19	11	Mar. 4	13	RU Camelop.		25	12	22	1
21	10	14	16	Mar. 16	2	R Crucis		22	23
23	9	24	19	V Carinæ		Mar. 2	23	23	12
25	7	Y Aurigae		Mar. 1	10	8	18	24	21
27	6	Mar. 2	6	8	2	14	15	25	19
29	5	6	3	14	19	20	10	26	18
31	4	11	0	21	12	26	6	27	17
SV Persei		13	20	28	4	S Crucis		28	15
Mar. 3	5	17	7			Mar. 1	18	29	14
14	8	21	14			6	10	30	12
25	12	25	10			11	3	31	11
RX Aurigæ		29	7			15	20	W Virginis	
Mar. 10	3					20	12	Mar. 2	13
21	18					25	5	19	20
						29	21		

Maxima of Variable Stars of Short Period not of the Algol Type.-Con

V Centauri

d	h
Mar. 6	1
11	12
17	0
22	12
28	0

R Triang. Austr.

d	h
Mar. 3	2
6	11
9	20
13	6
16	15
20	0
23	10
26	19
30	4

S Triang. Austr.

d	h
Mar. 5	19
12	3
18	11
24	19
31	2

S Normæ

d	h
Mar. 10	0
19	18
29	12

RV Scorpii

d	h
Mar. 3	20
9	22
15	23
22	1
28	2

RV Ophiuchi

d	h
Mar. 1	7
4	23
8	16
12	8
16	1
19	17
23	10
27	2
30	19

X Sagittarii

d	h
Mar. 4	19
11	20
18	20
25	20

Y Ophiuchi

d	h
Mar. 7	15
24	18

W Sagittarii

d	h
Mar. 5	21
13	12
21	2
28	16

Y Sagittarii

d	h
Mar. 4	19
10	13
16	8
22	2
29	21

U Sagittarii

d	h
Mar. 7	9
14	2
20	20
27	14

β Lyræ

d	h
Mar. 5	3
11	19
18	1
24	17
30	23

κ Pavonis

d	h
Mar. 6	11
15	13
24	15

U Aquilæ

d	h
Mar. 1	16
8	16
15	16
22	17
29	18

U Vulpeculæ

d	h
Mar. 4	0
11	24
19	23
27	23

SU Cygni

d	h
Mar. 2	7
6	3
10	0
13	20
17	16
21	12
25	9
29	5

η Aquilae

d	h
Mar. 1	4
8	8
15	12
22	17
29	21

S Sagittae

d	h
Mar. 5	23
14	8
22	17
31	2

X Vulpeculae

d	h
Mar. 4	17
11	1
17	8
23	16
30	0

X Cygni

d	h
Mar. 8	15
25	0

T Vulpeculae

d	h
Mar. 1	15
6	1
10	12
14	22
19	9
23	19
28	6

TX Cygni

d	h
Mar. 8	14
23	7

VY Cygni

d	h
Mar. 2	3
9	23
17	20
25	16

VZ Cygni

d	h
Mar. 3	18
8	15
13	11
18	8
23	5
28	2

Y Lacertae

d	h
Mar. 3	9
7	17
12	1
16	8
20	16
25	0
29	8

δ Cephei

d	h
Mar. 6	2
11	11
16	20
22	5
27	14

Z Lacertae

d	h
Mar. 10	12
21	9

RR Lacertae

d	h
Mar. 5	3
11	13
18	0
24	10
30	20

V Lacertae

d	h
Mar. 2	8
7	7
12	7
17	6
22	6
27	5

Lacertae

d	h
Mar. 3	21
9	8
14	19
20	5
25	16
31	2

SW Cassiop.

d	h
Mar. 6	7
11	17
17	3
22	14
28	0

RS Cassiop.

d	h
Mar. 5	22
12	5
18	12
24	20
31	3

RY Cassiop.

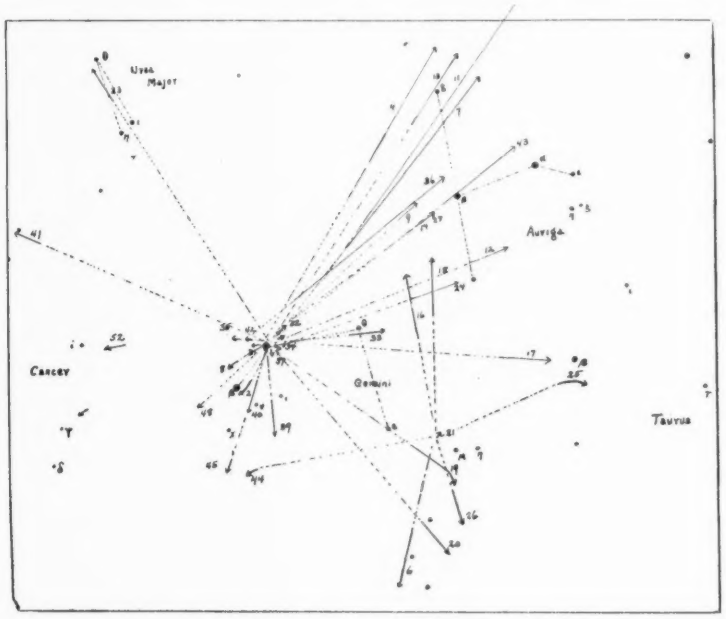
d	h
Mar. 7	2
19	5
31	18

COMMUNICATIONS QUESTIONS AND ANSWERS.

[This department is designed especially for the use of amateurs. Beginners are invited to send in their puzzling questions. The editors will try to see that answers are given to reasonable questions but will not hold themselves responsible for the correctness of the views expressed in the communications which may find place here. All communications should be brief.]

The Geminids, Dec. 12, 1910.—Next to the Perseid shower in August the Geminids seem to be the most consistent meteor shower. Although clouds and moonlight interfered this year there were an unusual number of Geminids close to the radiant, which seemed to be near α and ρ Gemini, a little S. W. There were a number from another radiant between μ and ε and No. 21 was almost head on, defining the radiant very clearly. Nos. 4 and 7 rivalled Sirius in brilliancy, leaving vivid greenish trails, No. 4 being very broad (represented on the map). No. 11 went almost clear across the sky. A number were very

markly curved, Nos. 35, 52, 19, 25, 2 and 44. In 1901 there must have been a good shower, for between 9:30 and 10:00 P.M. 32 were counted, when clouds interfered. One meteor, casting a distinct shadow even through the rapidly forming clouds was the brightest meteor that the writer has ever seen. In 1908, 58 were seen in an hour and a half, but again clouds interfered. This year 53 were observed between 9.20 P.M. and 2.08 P.M. clouds interfering, and a cold wind making frequent interruptions in observing.



THE GEMINIDS OF 1910.

Mag.	−3	−2	−1	0	1	2	3	4	5	6
No.	1	2	1	3	5	7	10	13	1	10

9:20 — 10:00	5	8 were reddish orange
10:00 — 10:17	7	6 " a distinct blue
* 10: 40— 11:02	9	2 " green and orange
11:02 — 11:31	4	37 " white
* 11:45 — 12:06	5	8 left distinct trails.
12:06 — 12:15	4	The ones near the radiant were
* 12:35 — 1:00	4	slow, the ones through Auriga
* 1:25 — 1:30	8	were very swift and long.
1:40 — 2:08	7	

* not observing

One fine Leonid was seen, shooting clear across the sky to the south.

ROBERT M. DOLE.

Jamaica Plain, Mass.

Resume of Sun Spot Observations at Mt. Holyoke, 1910.

Month	No. of Obs.	N. of Equator No. groups	Av. Lat.	S. of Equator No. groups	Av. Lat.	Av. No. at each Obs.	New groups
January	12	2	+3°.6	5	−10°.7	1.92	7
February	20	2	3.7	6	10.8	1.55	5
March	16	2	6.0	2	13.0	1.62	4
April	17	3	4.0	3	8.3	0.76	6
May	22	2	4.0	8	13.6	1.77	9
June	7	1	5.0	0	—	0.43	0
. . .							
September	8	0	—	5	13.8	1.62	5
October	21	2	3.3	14	12.2	1.90	14
November	19	0	—	1	8.0	0.11	0
December	13	0	—	2	15.5	0.54	2

Total number of observations..... 155
Total number of groups observed..... 52
Average number at each observation..... 1.35
Average latitude of northern groups. ..... +4°.2
Average latitude of southern groups..... −12°.2

The Sun was observed 38 times when no spots were seen; 17 of these observations were in November.

Most of the observations of the first half of the year were made by Miss Margo Lee Lewis; those of the second half by Miss Mary W. Clark.

Anne Sewell Young.

Mount Holyoke College
South Hadley, Mass.

Lunar Photography within the Reach of Amateurs.—Since the very moment in which the great French astronomer Arago announced to the Academy of Sciences in Paris, the discovery of photography by the French painter Daguerre, the astronomers thought that the beautiful art might have important applications in Astronomy.

And so it was. The surface of the Moon, the sun-spots, the solar spectrum, the stars were photographed, and photography was and is a very important help to astronomers. We must not forget that Halley's comet was discovered by means of photography by Professor Max Wolf, of Heidelberg, on September 12, 1909, when it was only of the 16th magnitude.

I have the pleasure to present to the readers of POPULAR ASTRONOMY a photograph of the Moon which I obtained on the evening of December 12, 1910, with a "Zeiss" telescope of 80 millimeters aperture, to which I adapted a simple camera, made of an wooden box, painted in black, outside and inside, and with an opening in the back of it so as to put either the ground glass or the chassis with the sensitive plate.

First I focus, the best I can, the image of the Moon on the ground glass, and then I put the image very low, in order to have time to cover the object-glass of the telescope, to uncover the plate and to give the exposure, which is almost instantaneous. We have to calculate the time so that when the exposure is given, the image of the Moon must be in the center of the plate.

After the plate is covered I treat it in the ordinary photographical way. In the negative of the photograph published with these lines, the large crater Schikard, which is one of the most beautiful on our satellite, is very plain.

THE MOON, Dec. 12, 1910.
PHOTOGRAPH TAKEN BY LUIS G. LEON.

The low prices of small telescopes and the easiness of modern photography put lunar studies within the reach of amateurs who do not have much money to spend in scientific investigations.

LOUIS G. LEÓN.

Mexico City, Dec. 17, 1910.

An Interesting Study for Amateurs.—For those just beginning the study of astronomy I want to urge the study of the Moon as a most fruitful pursuit. In the first place, so much can be done on the Moon with even a small telescope, say a three or even a two-inch, or even a pair of opera glasses, that one should not let such a good opportunity go by, wishing for a arger instrument or better knowledge. May I suggest just one or two fine objects for observation and the time when they may be seen. First, when the Moon is eighteen days and nine hours old, one may find on the eastern shores of Crisium a most remarkable feature. I call it two small peaks facing one another after the fashion of two horns. Even the passing of half an hour causes the perspective to change and adds an interesting detail or two. Once more when the Moon is from seven days and six hours up to seven days and about fifteen hours old, two most remarkable mountain peaks present themselves in fine manner on the shores of Imbrium, which has been in the field of light but a short time. At about the sixth hour one can look down between

these peaks. As a few hours pass, the form of each one shows itself under differences of light in most interesting manner. One of the peaks is round and conical, while the other is flattened. Just before and after quarter the details are surely grand. Many more details could be pointed out but one will readily discover many for himself. I find it convenient to keep one page in my note-book for each day of the Moon's age. Here I record from day to day and month to month all interesting details. One who can draw will find it helpful to note down sketches of interesting details. One soon comes to a limit to the amount of time and study he can profitably put on the stars or planets if he has but a small equipment but the Moon will take an almost unlimited amount of time. How fascinating too! I trust others may find the Moon such a faithful friend as I have.

RUEL W. ROBERTS.

Edgerton, Wis. Jan. 14, 1911.

GENERAL NOTES.

Felipe Valle.—The following account of the life and work of Felipe Valle, written by *F A. Bellamy* F.R.A.S., is taken from the December number of *Knowledge*.

"Felipe Valle, whose death took place on September 11, 1910, at an early age for astronomers, was in 1880 the first assistant observer and computer, in the Mexican Observatory at Chapultepec. Later he became the professor of physical astronomy and celestial mechanics at the Engineers School; the professor of spherical astronomy, of general topography, and of applied mathematics at the Military School; and, at last, the director of the newly-formed National Observatory at Tacubaya, in 1897. In 1907, Valle had at the Observatory a sub-director, three astronomers, seven assistants, a secretary and about twelve others.

"This Observatory was at first established at Chapultepec, in 1878, and was placed under the direction of Angel Anguiano; in 1883 it was transfered to Tacubaya, at a height of seven thousand and thirty feet, where work in the four distinct branches of astronomy, meteorology, magnetism and seismology is carried on. The contributions to astronomical publications made by Valle were not numerous. They consist mainly of observations upon comets and planets, and are to be found in the *Astronomische Nachrichten*, in volumes 123 to 139 (1889-1895). Both in Anguiano's time and throughout Valle's directorate a volume of several hundred pages, called the Annuario, was regularly published; the preparation of the manuscript was made by the observatory staff; and though not obvious in the printed books, a considerable amount of time and thought was given to these annals by Valle. Besides this publication a bulletin was issued occasionally, and reports were made to the government of Mexico; some of these reports may be found in the Annario.

"Since 1892 the main work of the Observatory was the execution of the section of the photographic Survey, $-10°$ to $-16°$, undertaken by Anguiano and Valle; with this, considerable progress has been made, but no volumes have as yet been published, though about one hundred charts have been printed and distributed. Valle visited England, Europe and the United States upon several occasions, to attend astronomical conferences in the name of the Mexican nation and science; he had a pleasant, affable and gentlemanly

manner, and he was deeply interested in his work. After he had returned from his recent visit to Europe his health commenced to decline and though none of those near him could believe his end was so near, he died quite suddenly at little before midnight, surrounded by his family."

Meteor Showers in 1911.—The following list of the more brilliant meteor showers is taken from Mr. W. F. Denning's catalogue, published in the *Companion to the Observatory* for 1911.

Date	Radiant α	Radiant δ	Meteors
Jan. 2-3	230	+53°	Swift; long paths.
Apr. 20-22	271	+33	Swift.
May 1-6	338	− 2	Swift; streaks.
July 28	339	−11	Slow; long.
Aug. 10-12	45	+57	Swift; streaks.
Oct. 18-20	92	+15	Swift; streaks.
Nov. 14 16	150	+22	Swift; streaks
Nov. 17-23	25	+43	Very slow; trains
Dec. 10-12	108	+33	Swift; short.

The Perseids, with a maximum on August 11, are visible for a considerable period and their radiant point exhibits a motion to E. N. E. amongst the stars. The following is an ephemeris:—

Date	Radiant α °	Radiant δ °	Date	Radiant α °	Radiant δ °	Date	Radiant α °	Radiant δ °
July 19	18.9	+50.5	July 29	29.3	53.8	Aug. 8	41.5	56.5
21	20.8	51.1	31	31.6	54.4	10	44.3	56.9
23	22.8	51.8	Aug. 2	33.9	55.0	12	47.1	57.3
25	24.9	52.5	4	36.4	55.5	14	50.0	57.7
27	27.1	53.2	9	38.9	56.0	16	52.9	58.0

A Daylight Occultation of σ Sagittarii.—In Vol. XXI, No. 2, of the *Journal of the British Astronomical Association*, we find an interesting account of a daylight occultation, by Mr. E. H Beattie of WestPoint, Mosman, N. S. W.

"The times for this occultation were:—

For immersion, August 17^{d} 4^{h} 32^{m} 47^{s} } Sydney Standard Time
" emersion, 5 43 29 }

Angles from the north point at immersion, 98°: at emersion, 266°.

"As the sky was very bright, the Sun being, of course, some distance above the horizon, and as the heat of the day was causing some unsteadiness in the atmosphere, I had some doubt as to finding a star of magnitude 2.1. However, on setting the equatorial (6½-inch refractor) on the position and inserting a Kelner eye-piece, the star came out very clear and bright, so that there was no difficulty in accurately noting the instant of disappearance, which was quite sharp and sudden.

The instrument was then left with the driving clock in gear and the telescope running in the star's position, and on returning to the eyepiece a few minutes before the time of expected reappearance, it was noted that, although still quite pale and blue to the naked eye, in the field of the instrument the sky had a much darker appearance, almost black in contrast with the Moon's bright limb, and when the star appeared it looked intensely brilliant and very beautiful as it leapt away into the dark void.

The observed times were:—

For immersion	$4^h\ 32^m\ 41^s$	} Standard
For emersion	$5\ \ 44\ \ 15$	} Time

Although the time for immersion agrees fairly well with the calculated time, there seems to be a discrepancy somewhere with regard to the emersion, which took place 46 seconds later than anticipated."

Night Letter Service.—A majority of the subscribers to astronomical telegrams favoring the Night Letter service outlined in our circular letter of Dec. 10, it has been decided to adopt the following plan:—

On and after January 1, 1911, position messages will be distributed in plain language by Night Letter on the night of or following, the receipt of the original announcement at this Observatory, except to subscribers who file special requests to have all announcements, or those of a specified character, telegraphed to them immediately, in which cases such announcements will be telegraphed in cipher code.

Elements and ephemerides will be distributed only by mail bulletin, except to subscribers who have especially asked that they be sent by telegraph, in which cases they will be telegraphed also in cipher as at present.

Announcements for distribution may be sent to this Observatory by ordinary telegram, or by Night Letter, at the discretion of the sender. Messages in the present cipher code will be received as heretofore. It is suggested, however, that positions sent by Night Letter be expressed, whenever possible, with the same degree of accuracy as is prescribed in the regular cipher telegram.

Announcements of special interest or importance may, at the discretion of this Observatory, be telegraphed immediately, in cipher, as at present.

EDWARD C. PICKERING.

Harvard College Observatory, Dec. 31, 1910.

Erratum.—Among the variable star notes in No. 180, December 1910, there appears a note on *New Elements of the Light Curve of the Variable*

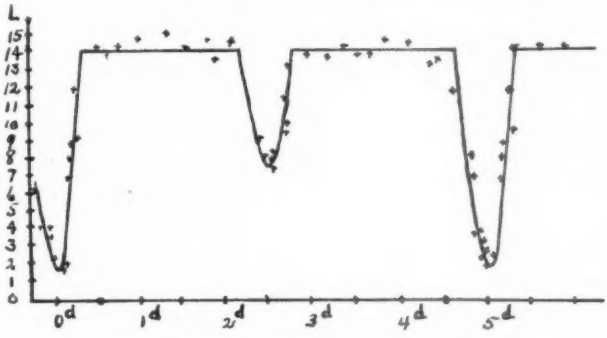


FIG. 1. LIGHT CURVE OF RT LACERTÆ

Star SY Cassiopeiæ by M. Luizet. The note was translated from the *Bulletin Astronomique*. Our attention has been called to the light curve, which is evidently of the β Lyrae type, while the note goes to show that the star has a

variation of the δ Cephei type. The error was cleared up by a recent letter from M. Luizet in which he shows that the cuts to illustrate two of his notes

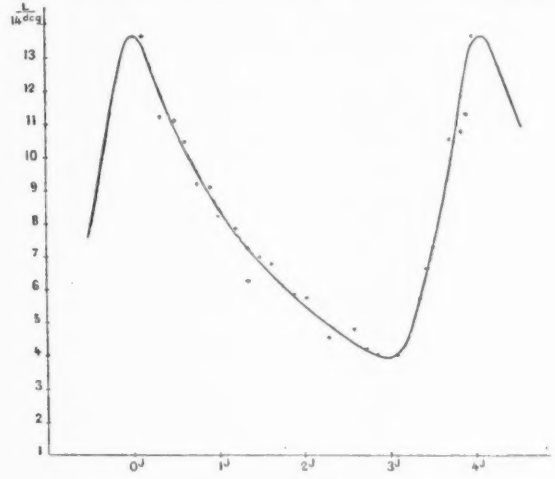


FIG. 2. LIGHT CURVE OF SY CASSIOPEIAE

in the *Bulletin Astronomique*, were interchanged. The curve Fig. 1. published in POPULAR ASTRONOMY No. 180 is the curve of R T Lacertae, an Algol Type variable with a period of 5d 1h 46m 34s.

Fig. 2. Shows the light curve of S Y Cassiopeiae

An Appeal to Amateur Astronomers to make Systematic Observations of Meteors. In Ciel at Terre, the Bulletin of the Belgium Society of Astronomy, of December 1910, there appears an article under the above title of which the following is practically a translation.

Many amateur astronomers think it impossible to carry out their desire to make practical observations because they have no instruments at their disposal. Never-the-less the study of meteoric astronomy offers to all those who love nature an opportunity to render valuable service to science, if they are situated in a place favorable for observations and have a little patience. The questions that are related to the appearance of meteors are numerous, and it requires a large number of observations extending through a long series of years in order to find the solutions of the problems that present themselves. Almost anyone can contribute to this work which does not require any great degree of technical knowledge. In order to obtain the desired result it is necessary to have a large number of observers scattered all over the Earth. It is also essential that each one be able, summer and winter, to place his services at the disposal of the science, in observing during certain hours of the night. In order that these observations may be conclusive they should be made consecutively and according to some common plan, and there should be some central organizations which would attend to the final compilation of them. These observations, though they may seem insignificant to the

isolated observers, nevertheless, when combined with those of other observers, represent important documents as the final result.

In March 1908, M. Riegler at Vienna and M. C. Birkenstock at Anvers agreed on forming an organization for the systematic observation of meteors. That was transformed in June 1910 into an international organization which has taken the name *Central Meteoric Bureau*. This Bureau has as its purpose the grouping around itself all those who are interested in that particular branch of astronomy, the study of meteors, and the gathering together of all the observations made according to a definite plan. The small group of observers, which will certainly grow and gradually spread over the entire Earth, has sent to the central Bureau, which was then situated at Anvers, some six-thousand systematic observations, not mentioning the bolides and areolites. The seat of the Bureau is temporarily at Hamburg where the director and founder, Mr. Charles Birkenstock, lives. The simplicity of our plan, as will be seen, permits at least the initiated to become interested in our plan.

1. All those who observe a definite region of the sky during a given time ought to count the number of falling stars that appear and to designate approximately the durations of their visibility.

(a) The observer must attend very carefully to a definite region of the sky selected according to local conditions, preferably a region to the east.

(b)He must count each one of the falling stars that appear in the region observed, taking great care that not even the faintest escape his observing and making note of it.

(c) The part of the sky observed, which should always remain the same, should not extend over more than 90° since a larger region would make careful observations impossible. One should observe preferably due N. E. or S. E. The attention should be centered solely upon meteors. But meteors seen by chance in another region of the sky have no particular importance unless they are of unusual brilliancy.

(d) He should note as precisely as possible the length of the duration of the appearance of the meteor, and also the moment when he began and ended the observations, being careful to state whether he is using Greenwich time or some other. The duration of the periods of observation should be at least one hour.

2. The observer should indicate the circumstances of his observations, that is to say, the condition of the sky, moonlight or not, if so at what phase, local conditions such as light reflections, etc.

These are the more important points to which it will be necessary to conform, nevertheless,

(3) It is useful also to indicate the brightness, (according to stellar magnitudes), the velocity, the color, etc. of the meteors and the general direction of the path.

4. All these facts should be noted rapidly so that no meteor may escape notice while one is writing, otherwise, the observations will not be very systematic. With a little practice it is easy to organize the work.

5. Those who find the work very interesting may further care to sketch the paths of the meteors upon sky charts. In order not to lose any time in comparing the sky with the chart, the observer may draw only those paths which have been definitely followed and which can be drawn quickly in an accurate manner.

The remark 4 above is addressed especially to observers who work with the charts. It is preferable in this case that there be two, so that while one

observes, the other may, from his dictation, make the notes. The *Central Meteoric Bureau* will gladly give to all those, who desire to take part in carrying out this work, definite explanations in the use of the charts. The undersigned will send monthly to all his colaborers the lists of observation which he asks to be returned to him filled out monthly also. The charts of the sky will be sent very cheaply at the request of those who are interested.

It is necessary that the observer be comfortably situated. He should preferably be seated in an arm-chair placed so that he can see, without fatigue, the zenith of the region to be observed. Before him he should place a small writing table with the charts of the sky and a dark lantern whose light, of course, must not interfere with his observations. The observation should be made out of doors, on a terrace or a housetop possibly.

It is entirely possible that not a single meteor should appear in an hour of observation. This negative result is of equal importance with the positive results, and a note somewhat as follow should be made "During an observation from 11 to 12 G. M. T. March 1, sky clear, no meteor was seen."

Before closing this article we desire to add some remarks to which the reader is asked to give especial attention.

1. The observations ought not be made unless the observer can provide a favorable place where he will not be disturbed either by the lights of the city or by the reflections from the surroundings, even where he can have an unlimited view. Observations made from an open window would not be entirely acceptable.

2. Observations are not really useful and cannot give reliable results unless the condition of the sky is favorable in the region observed. Stars of the fourth magnitude or less ought always to be visible. If the sky is constantly overcast with thin clouds or if the Moon is too bright, observations ought not be made, for the number of meteors that will be visible will be influenced by these unfavorable conditions and the observations will not fulfill their purpose. Many of our colaborers, moved by too great zeal, are wrong in observing under unfavorable conditions. They ought never to forget that the results thus obtained are probably not accurate and that they therefore tend to spoil the conclusions when they are combined with good observations. If there is a clear Moon, that fact should always be indicated together with its phase and its position in the sky. For example, "Moon in the south, first quarter." It is well to add to what degree the light from the Moon would affect the observations, by indicating as precisely as possible the faintest stars that are visible in the region observed. For example, "Stars of the fourth magnitude easily visible."

3. The experienced observer can estimate the relation between the number he observed and the number that actually appeared. He could indicate, for example, under the heading, "Condition of the sky," "sky clear, lights of the city affected the observations slightly, but stars of the fourth magnitude are visible." At the end of his observations he should add the remarks thus: "The number" of meteors observed correspond closely to the actual number that appeared, "or possibly, "The number of meteors indicated differs slightly probably from the actual number that appeared." These remarks should of course be of a rigorous scientific accuracy.

We close with the hope that many amateurs will be disposed to assist in our work and we ask them to write to the address given below. In order to spare time and money we ask only those to write who desire to give serious attention to their work, and who can use a place suitably situated for observations. The person who wants to take up the work is asked to specify in his first letter as nearly as possible his geographical latitude and longitude.

(Signed) Charles Birkenstock,
Director-Founder of "The Central Meteoric Bureau."
Landwehr, 16 Hamburg Germany.

We give this to our English readers with the feeling that possibly some of them have made or are willing to make observations of the kind specified, The subject of meteors cannot fail to interest many, and the Central Bureau opens the way for those who have time to make observations to contribute to a large undertaking when otherwise their work would be more or less at random.